

595

# AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY

*Founded by Aleš Hrdlička, 1918*

MANAGING EDITOR

S. L. WASHBURN  
The University of Chicago

ASSOCIATE EDITORS

T. D. McCOWN  
University of California

STANLEY M. GARN  
Fels Research Institute  
Yellow Springs, Ohio

F. CLARK HOWELL  
University of Chicago

MILDRED TROTTER  
Washington University  
School of Medicine

BOOK REVIEW EDITOR

FRED P. THIEME  
University of Michigan

Organ of the American Association of Physical Anthropologists

NEW SERIES — VOLUME 15  
MARCH, JUNE, SEPTEMBER,  
DECEMBER, 1957

PUBLISHED BY

THE WISTAR INSTITUTE OF ANATOMY AND BIOLOGY  
PHILADELPHIA, PA.



Digitized by the Internet Archive  
in 2024



# CONTENTS

## No. 1 MARCH 1957

H. J. J. BLACKWOOD. The double-headed mandibular condyle. Six figures ..	1
T. D. STEWART. Distortion of the pubic symphyseal surface in females and its effect on age determination. Five figures .....	9
W. W. HOWELLS. The cranial vault: Factors of size and shape. Six figures ..	19
N. C. TAPPEN. A comparison of split-line patterns in the skulls of a juvenile and an adult male gorilla. Two figures .....	49
F. GAYNOR EVANS AND CHARLES W. GOFF. A comparative study of the primate femur by means of the stresscoat and the split-line techniques. Thirty-one figures .....	59
R. SINGER, O. E. BUDTZ-OLSEN, P. BRAIN AND J. SAUGRAIN. Physical features, sickling and serology of the Malagasy of Madagascar. Six figures .....	91
GEORGE E. BROMAN, JR. Precondylar tubercles in American Whites and Negroes. Six figures .....	125
DONALD F. HUELKE. A study of the formation of the sural nerve in adult man. Five figures .....	137
BRUCE CHOWN AND MARION LEWIS. The Kell antigen in American Indians. With a note about anti-Kell sera .....	149
<i>Comments and Communications:</i>	
HOWARD V. MEREDITH. Concurrent fat loss and gain: Addendum .....	157
<i>Book Notes</i> .....	159

## No. 2 JUNE 1957

G. W. G. BIRD, T. K. JAYARAM, ELIZABETH W. IKIN, A. E. MOURANT AND H. LEHMANN. The blood groups and haemoglobin of the Gorkhas of Nepal.	163
P. KYNASTON THOMAS AND D. G. FERRIMAN. Variation in facial and pubic hair growth in white women. Two figures .....	171
MELVYN J. BAER AND JOSEPHINE DURKATZ. Bilateral asymmetry in skeletal maturation of the hand and wrist: A roentgenographic analysis .....	181
J. H. SCOTT. Muscle growth and function in relation to skeletal morphology. Nine figures .....	197

FREDERICK S. HULSE. Linguistic barriers to gene-flow. The blood-groups of the Yakima, Okanagon and Swinomish Indians .....	235
HOWARD V. MEREDITH. Change in the profile of the osseous chin during childhood. Three figures .....	247
KENNETH P. OAKLEY. Stratigraphical age of the Swansecombe skull .....	253
DUK JIN YUN. Eruption of primary teeth in Korean rural children .....	261
S. L. WASHBURN. Ischial callosities as sleeping adaptations. Two figures...	269
J. M. TANNER AND R. H. WHITEHOUSE. The Harpenden anthropometer. A counter-type anthropometric caliber. One figure .....	277
JOHN HILLABY. The Kwangsi jaw. One figure .....	281
Viking Fund Medalist for 1956 (Mildred Trotter) .....	287

*Reviews:*

H. HOFER, A. H. SCHULTZ AND D. STARK. <i>Primatologia: Handbook of primatology. Reviewed by James A. Gavan</i> .....	293
I. W. CORNWALL. <i>Bones for the archaeologist. Reviewed by Arthur J. Jelinek</i> .....	296
JAMES COUPER BRASH, H. T. A. McKEAG AND JAMES H. SCOTT. With an appendix by Miriam L. Tildesley. <i>The aetiology of irregularity and malocclusion of the teeth. Reviewed by Stanley M. Garn</i> .....	297

### No. 3 SEPTEMBER 1957

MARCUS S. GOLDSTEIN. Skeletal pathology of early Indians in Texas. Two figures .....	299
STANLEY MARION GARN, KALEVI KOSKI AND ARTHUR B. LEWIS. Problems in determining the tooth eruption sequence in fossil and modern man. Five figures .....	313
PETER A. STEWART, RICHARD P. SMITH, ISAAC BEHAR AND ARTHUR J. RIOPELLE. Galvanic skin response in monkeys with prehensile tails. Two figures .....	333
JOHN BUETTNER-JANUSCH. The distribution of ABO blood groups in a sample of hospital patients receiving blood transfusions .....	341
R. T. SIMMONS AND J. J. GRAYDON. A blood group genetical survey in Eastern and Central Polynesians .....	357
RICHARD W. YOUNG. Postnatal growth of the frontal and parietal bones in white males. Three figures .....	367
FREDERICK P. THIEME AND CHARLOTTE M. OTTEN. The unreliability of blood typing aged bone .....	387

THOMAS W. MCKERN. Estimation of skeletal age from combined maturational activity. Four figures .....	399
--	-----

*Reviews:*

J. HIERNAUX. Analyse de la variation des caractères physiques humains en une région de l'Afrique centrale: Ruanda-Urundi et Kivu. Reviewed by W. W. Howells .....	409
---	-----

KURT BRØSTE, J. BALSLEV JØRGENSEN, C. J. BECKER AND JOHANNES BRØNDSTED. Prehistoric man in Denmark. (A Study in Physical Anthropology.) Reviewed by W. S. Laughlin .....	413
--	-----

<i>Book Notes</i> .....	415
-------------------------	-----

THE AMERICAN ASSOCIATION OF PHYSICAL ANTHROPOLOGISTS. Proceedings, abstracts and list of members .....	421
--	-----

## No. 4 DECEMBER 1957

KALEVI KOSKI AND STANLEY MARION GARN. Tooth eruption sequence in fossil and modern man. Five figures .....	469
--	-----

WILLIAM WALTER GREULICH. A comparison of the physical growth and development of American-born and native Japanese children. Eleven figures .....	489
--	-----

THOMAS MURPHY. The chin region of the Australian aboriginal mandible. Five figures .....	517
--	-----

LUCILE E. HOYME. The earliest use of indices for sexing pelves. One figure .....	537
--	-----

R. T. SIMMONS, N. M. SEMPLE, J. B. CLELAND AND J. R. CASLEY-SMITH. A blood group genetical survey in Australian aborigines at Haast's Bluff, Central Australia .....	547
--	-----

FRANCISCO M. SALZANO. The blood groups of South American Indians ....	555
---	-----

BARBARA J. BOUCHER. Sex differences in the foetal pelvis. Four figures ..	581
---	-----

PAUL T. BAKER AND RUSSELL W. NEWMAN. The use of bone weight for human identification. Four figures .....	601
--	-----

*Reviews:*

SHELDON GLUECK AND ELEANOR GLUECK. Physique and delinquency. Reviewed by Stanley M. Garn .....	619
--	-----

WILTON M. KROGMAN AND VIKEN SASSOUNI. A syllabus in roentgenographic cephalometry. Reviewed by A. H. Craven and R. E. Moyers .....	621
--	-----

F. GAYNOR EVANS. Stress and strain in bones. Their relation to fractures and osteogenesis. Reviewed by William J. L. Felts .....	622
--	-----

JOSEPH H. GREENBERG. Essays in linguistics. Reviewed by Herbert H. Paper .....	624
--	-----





GIFT TO THE UNIVERSITY OF PITTSBURGH  
by JOHN GILLIN

THE DOUBLE-HEADED MANDIBULAR CONDYLE

H. J. J. BLACKWOOD

*Department of Pathology, Royal Dental Hospital of London*  
*School of Dental Surgery, University of London*

SIX FIGURES

An unusual developmental anomaly of the mandibular condyle in which the condylar head is divided anteroposteriorly into two separate articulating surfaces has been described by Hrdlička ('41). He reported the condition in 21 human jaws of varied racial origin, 12 of which showed a more or less complete division of the condylar head while in the remainder though the division was incomplete, the tendency towards such division was clearly marked. The only account of this anomaly in the living subject was given by Schier ('48). He detected the condition radiographically in a patient's right mandibular condyle; the left condyle presented a normal outline.

No satisfactory explanation appears to have been offered as to the cause or meaning of this anomaly. As Hrdlička pointed out there is no instance in the phylogenesis of the bone which might account for the anomaly nor is there any indication that a mechanical injury to the bone could account for the development of this defect. He postulated that some secondary mechanical factor which interfered with the ossification of the condyle must therefore be responsible. As a possible analogy, he mentions the characteristic cleavage of the basilar process of the occipital bone which may be caused by an aberrant artery, but dismisses any similar explanation in relation to the development of the anomaly in the mandibular condyle.

In a recent study of the development and growth of the mandibular condyle the present author was impressed by the extent to which the condylar cartilage, during its early stages of growth, is divided by well-vascularised fibrous tissue septa. The existence of these septa in the growing cartilage has already been noted by Macalister ('55) and their presence interpreted as evidence of rapid growth, a statement with which the author is in agreement. It was thought, therefore, that the persistence of such a septum in an exaggerated form within the growing cartilage might lead to an error in development of the future condyle, giving rise to a bifid appearance similar to that described by Hrdlička.

#### *Histological observations*

From examination of 10 human foetal skulls of ages varying from 8 weeks to 28 weeks it was found that the septa

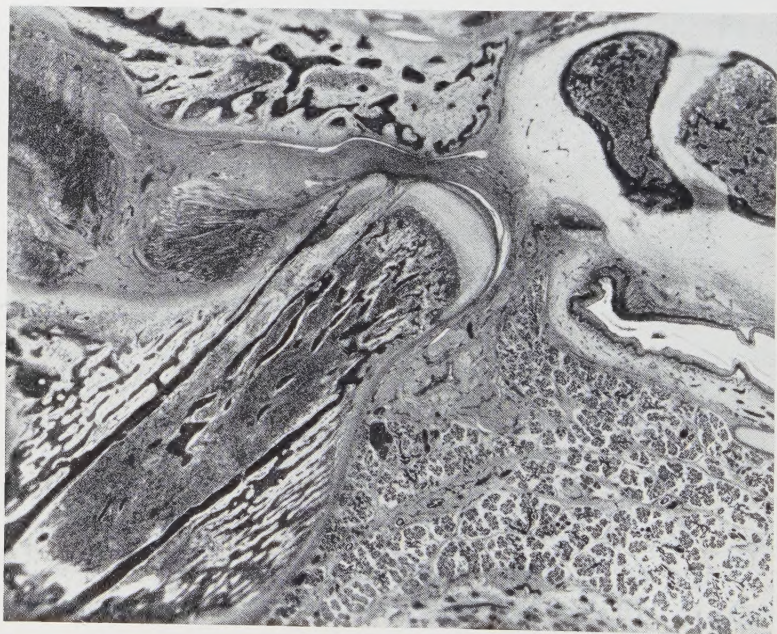


Fig. 1a Human foetal condyle aged 20 weeks showing a deep fibrous tissue septum extending from the cartilage into the medullary cavity of the ascending ramus. (Haematoxylin and Eosin; magnification  $\times 7$ .)



first appear in the condylar cartilage at approximately 20 weeks of intra-uterine life and even at this age they can be seen to extend for a considerable distance into the medullary cavity of the developing ascending ramus (figs. 1a and b).



Fig. 1b Higher magnification of the septum which is composed of spindle fibroblasts and small blood vessels and is separated from the adjacent haemopoietic marrow by a thin bony trabeculum. (Haematoxylin and Eosin; magnification  $\times 40$ .)

Thereafter, the number of septa within the cartilage appears to increase towards full term and reaches a maximum several months after birth (fig. 2). These structures remain a constant feature of the condylar cartilage during the first year or more after birth. Towards the commencement of the second

year of life the septa become fewer in number (fig. 3) and the cartilage begins to "even out" until it assumes a uniform thickness over the head of the condyle, as in the more adult form. In the present study 12 human temporomandibular joints ranging from full term to two years of age have been

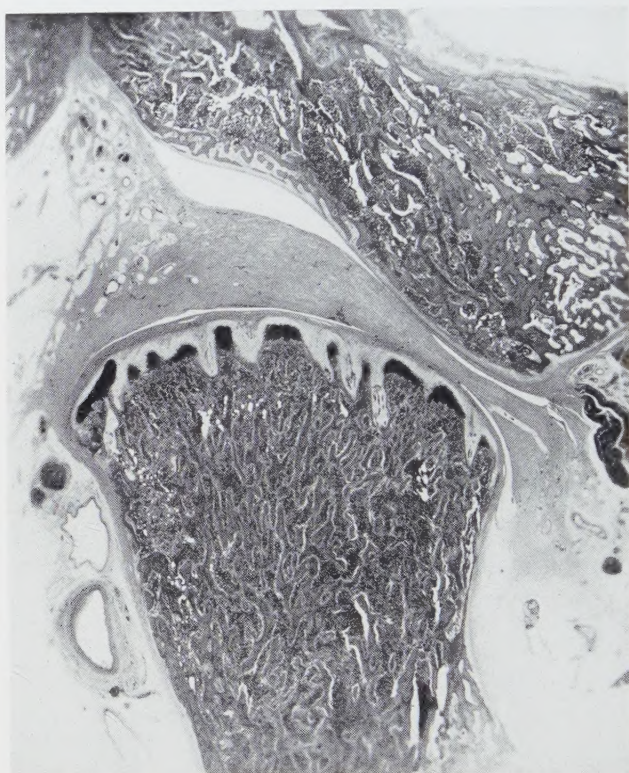


Fig. 2 A human mandibular condyle aged 4 months showing the numerous fibrous septa penetrating the cartilage layer. (Haematoxylin and Eosin; magnification  $\times 6$ .)

examined but no septa were found later than 19 months, and in the specimen of that age only one small septum remained (fig. 4). Prior to 19 months the septa were present in all the condylar cartilages examined.

The septa are composed of solid cords of spindle-shaped cells resembling fibroblasts, and carry a rich supply of blood



vessels. These vessels enter the septum only from its free end within the medullary cavity (fig. 5) and course upwards towards the cartilage where they ramify in the deeper layers (fig. 6) but never penetrate beyond the intermediate cell layer. The vessels vary in calibre but are seldom more than

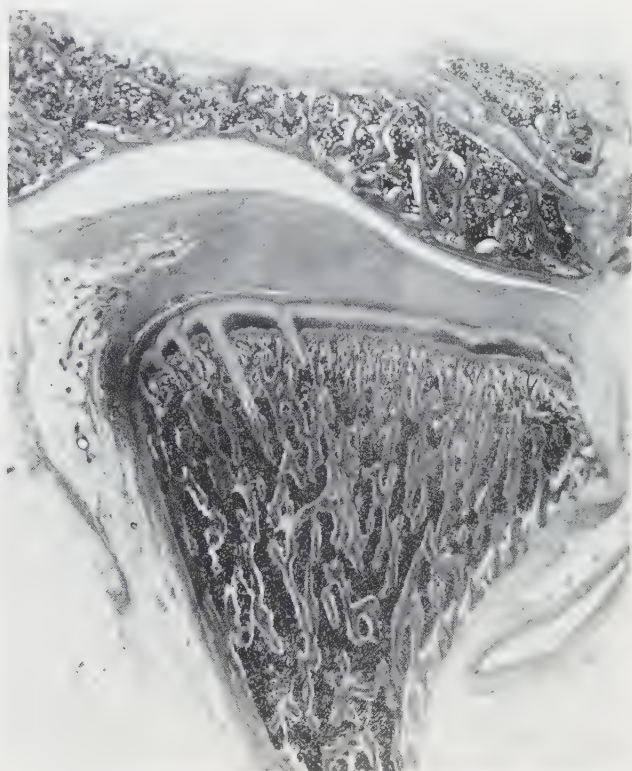


Fig. 3 Commencing reduction in the number of fibrous septa in a mandibular condyle at the age of 7 months. (Haematoxylin and Eosin; magnification  $\times 6$ .)

large capillaries. The longer septa which extend deeply into the medullary cavity are bounded by thin trabeculae of bone which have formed on a "scaffold" of calcified cartilage matrix (fig. 5), but the more numerous, shorter septa are bounded only by the adjacent proliferating cartilage cells.

## CONCLUSION

In view of the histological evidence presented it would appear to be a reasonable assumption that should one of these septa persist, perhaps in a more extensive and exaggerated form than those illustrated here, then an uneven or bifid development of the mandibular condyle might easily result. Alternatively, rupture of some of the small vessels within the cartilage as a result of mechanical injury to the condyle

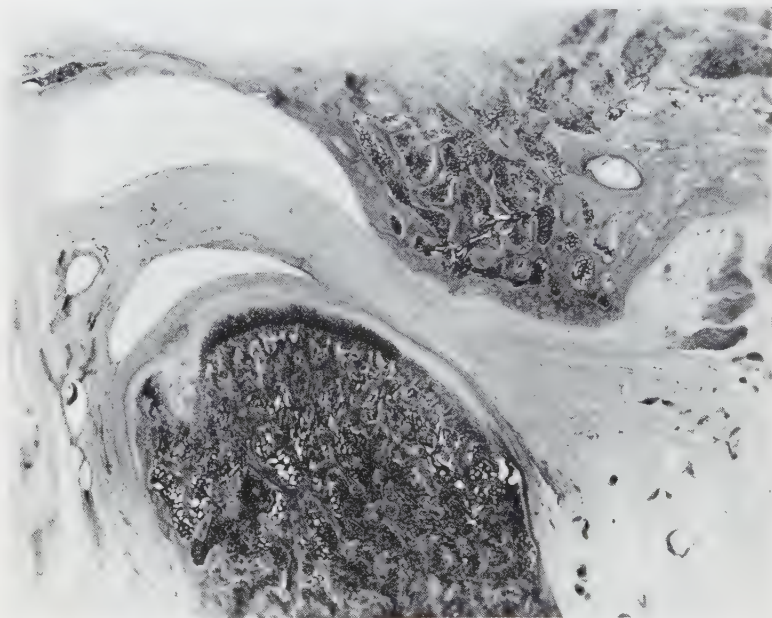


Fig. 4 One large septum which has persisted in a mandibular condyle until the age of 19 months. (Haematoxylin and Eosin; magnification  $\times 6$ .)

early in post-natal life might cause a localised impairment of ossification and so lead to abnormal development of the condyle. These theories are offered in an attempt to explain this rare but interesting developmental defect which, judging from the one case reported *in vivo*, is unlikely to cause any grossly disturbing clinical signs or symptoms but, as Hrdlička pointed out, may lead to premature arthritic changes within the joint.

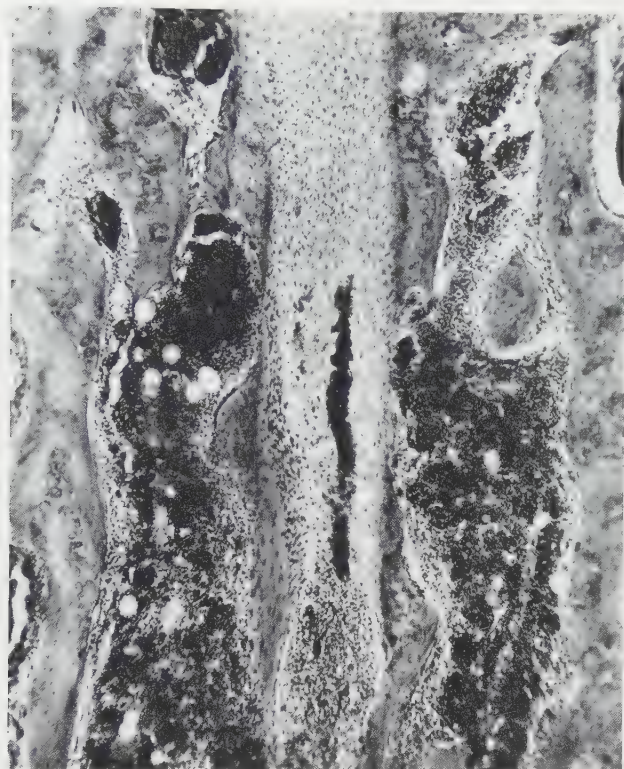


Fig. 5 A large blood vessel entering a septum from the medullary cavity. The septum is bounded laterally by thin bony trabeculae. (Haematoxylin and Eosin; magnification  $\times 65$ .)

#### SUMMARY

Well-vascularised fibrous tissue septa have been demonstrated as a constant histological finding in the growing condylar cartilage of the human mandible from 20 weeks intra-uterine life to 19 months post-natal life. It is suggested that the persistence of one of these septa into adolescent life or the possible rupture of some of the blood vessels contained within the septa might so impair the ossification of the condyle as to cause the bifid development of the condylar head described by Hrdlička.





Fig. 6 Numerous blood vessels which extend into the intermediate layer of the cartilage in a mandibular condyle at the age of 4 months. (Haematoxylin and Eosin; magnification  $\times 65$ .)

#### LITERATURE CITED

- HRDLIČKA, A. 1941 Lower Jaw: Double Condyles. *Am. J. Phys. Anthropol.*, 28: 75-89.
- MACALISTER, A. D. 1955 The Development of the Human Temporo-mandibular Joint. A Microscopic Study, *Austral. J. Den.* 59: 21-27.
- SCHIER, M. B. A. 1948 Temporo-mandibular joint—consideration of its probable sequelae and report: condyle—double head—in a living person, *Dent. Items Interest.*, 70: 1095-1109.



# DISTORTION OF THE PUBIC SYMPHYSEAL SURFACE IN FEMALES AND ITS EFFECT ON AGE DETERMINATION

T. D. STEWART

*Division of Physical Anthropology,  
U. S. National Museum, Washington, D. C.*

FIVE FIGURES

The skeletal character which is the subject of this paper must have been observed many times by anthropologists, but, so far as I can determine, it has not been explained heretofore. Since my interpretation is the outgrowth of certain experiences and is not supported by figures obtained through planned research, I feel that I should tell how I arrived at my point of view.

During a period of 4 months in 1954-55 I examined carefully the skeletons of 450 American soldiers for age changes. In each case the examination included the symphyseal surfaces of the pubic bones, because it was desired to make a cast of the best preserved side. The cast, in turn, had to be compared with the bone to make certain of the accuracy of the replica. This experience gave me a clear concept of the appearance of this region in the male. Figure 1 shows the symphyseal surfaces of three typical casts from the Army series. Here the smooth sweeping curve of the dorsal edge (on the left side in the picture) is noteworthy as being characteristic throughout the age range 17-50.

The following winter I undertook for another purpose (Stewart, '56) a study of Eskimo skeletons of both sexes and again included observations on the symphyseal surface. When on this occasion I began encountering symphyseal surfaces unlike anything I had seen in the Army males—

surfaces irregular in contour and rough in appearance, it seemed to me that they must be from older individuals than those encountered in the Army series. Gradually, however, I became aware — from the evidence of the teeth, the sutures, and the joints in general — that some of these individuals were far from being senile. Also whenever a symphyseal



Fig. 1 Three casts of pubic bones from the Korean war dead series. Note that in normal cases such as these the dorsal edge of the symphyseal surface (here on the left side) presents a smooth sweeping curve. (*Left to right*: No. 139, age 18; no. 223, age 24; no. 333, age 29).

surface with these abnormal features appeared, the skeleton was in my judgment *always* female. On the other hand, these irregularities were rarely, if ever, observed in subadult and young adult females. In figure 2 three distorted symphyseal surfaces of female Eskimos are compared with three typical symphyseal surfaces of male Eskimos. Note that the Eskimo males, like the Army males, show a smooth curving dorsal



Fig. 2 Three male (left) and three female (right) pubic bones of Eskimos. Note that the symphyseal surfaces of the males are normal like those in figure 1, whereas in the females the dorsal edges of these surfaces are distorted. (*Left to right*: U.S.N.M. nos. 332,535; 279,583; 332,548; 339,031; 339,132; 339,132).

edge, but that the Eskimo females show a dorsal edge varying from straight to irregular. In this view the three female symphyseal surfaces do not show irregularities in the plane of the surface which often accompany the changes in the dorsal edge.

The irregularity in the dorsal edge of the symphyseal surface in certain Eskimo females is due to the formation of pits undermining this edge. Figure 3 contrasts the inner sides of the pubic bones of male and female Eskimos. Pits on the inner side and just lateral to the symphyseal surface, such as seen here in the females — or for that matter even small pits — are never seen in males, and are seldom, if ever, seen in subadult females. Incidentally, although Eskimos have been used to illustrate this condition, American Indians could have been used just as well.

Now while I was reaching these conclusions, Dr. T. W. McKern, was in my laboratory studying the casts obtained on the Army series. Previously, while at the University of California, he had followed the studies of Sheilaigh Thompson Brooks which have been reported in this *Journal* ('55) under the title "Skeletal age at death: The reliability of cranial and pubic age indicators." Also, both of us had copies of her manuscript and in addition McKern had a set of her pubic models. Upon reading the Brooks manuscript in the light of the observations outlined above, McKern and I concluded that her "rough" type of symphyseal surface (see Brooks, '55, pp. 584-5; fig. 25 in plate 4) represents an abnormal condition found only in females. Identification of the type with the female sex was substantiated by the Brooks models. As figure 3 shows, the sex of the individual often is apparent from the symphyseal end of the pubic bone alone. In other words, her "rough" types were obtained from female specimens.

Supporting evidence for this position is supplied by available mortality curves based on the Todd phases of pubic



Fig. 3 Two male (left) and two female (right) pubic bones of Eskimos seen from behind. Note the pits undermining the dorsal edge of the symphyseal surface in the females. They are never seen in males. Other sex differences seen in this view are: (1) Medial border of the inferior ramus convex in the males, concave in the females; (2) medial portion of the bone (that is, the area between the obturator foramen and the symphyseal surface) triangular in the males, rectangular in the females (thus making the inferior extremity of the symphyseal surface more prominent in the females). (*Upper left*: U.S.N.M. no. 332,539; *upper right*: 332,548; *lower left*: 279,583; *lower right*: 279,585).



metamorphosis (Todd, '20-'21). In 1948 Brooks used these phases to judge the ages at death in "somewhat under 400 individual skeletons" of California Indians (her figs. 1 and 2). Then in 1953 she repeated this process for a second series of about 70 skeletons (her fig. 3).<sup>1</sup> I have combined these data in my figure 4 to show the striking sex difference. Figure 5 shows Hooton's ('30) list of phases for the peccos collection arranged in the same way.<sup>2</sup> These histograms indicate that many more females than males survived to old age in ancient times. But may not the excess of old females simply be due to mistaking abnormal young or middle-aged symphyseal surfaces for ones that are old? Indeed, Brooks admits (p. 585) having "previously" mistaken her "rough" type for an anomalous Phase X, but she fails to indicate whether her histograms had been corrected. I suspect that they were not. Certainly Hooton was not aware of this source of error.

Brooks explains that the observational difference between the "rough" and Phase X types "rests on the recognition of the difference between the break-down of old bone and the appearance of a new surface of smooth bone moving dorso-ventrally over the previous young surface of a Phase IV

<sup>1</sup>The graduations on the ordinates in these three histograms are incorrectly labelled: They represent number of cases and not age in years.

<sup>2</sup>Hooton states that he was unable to distinguish in all cases between Todd's pubic phases (p. 21). It has been necessary therefore to combine the data in his table II-4, in order to construct figure 5, as follows:

MALES	FEMALES
Phase 1 = 1 and 1-2	1 = 1
Phase 2 = (none)	2 = 2
Phase 3 = 2-3 and 3	3 = 3
Phase 4 = 4	4 = 3-4 and 4
Phase 5 = 4-5 and 5	5 = (none)
Phase 6 = 6	6 = 5-6 and 6
Phase 7 = 7	7 = 7
Phase 8 = 7-8 and 8	8 = 7-8 and 8
Phase 9 = 8-9, 8-10 and 9	9 = 8-9 and 9
Phase 10 = 9-10 and 10	10 = 9-10 and 10



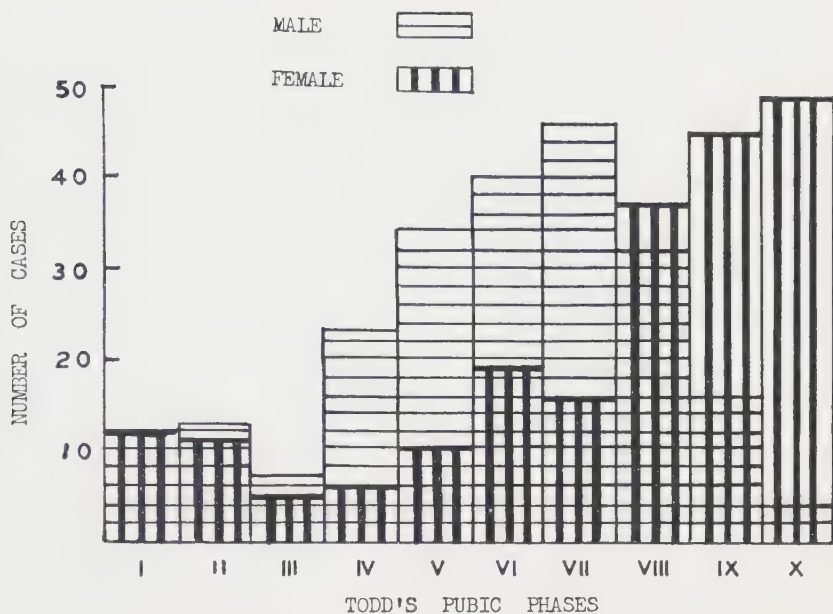


Fig. 4 Mortality curves for California Indians as determined by Brooks ('55) using Todd's pubic phases for ageing the individual skeletons. Data from her figures 1-3 are here combined into a single histogram. Reasons are advanced in the text for suspecting the extent of the sex differences in mortality in old age shown here.

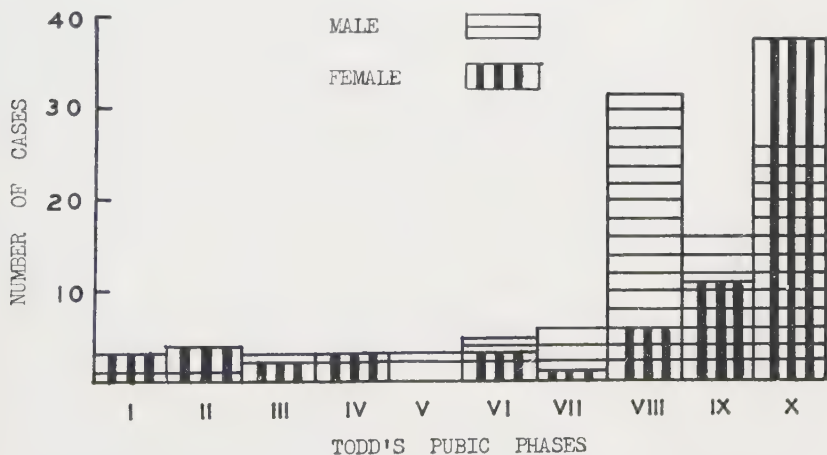


Fig. 5 Mortality curves for the Indians of Pecos Pueblo, New Mexico, as determined by Hooton ('30). Data from his table II-4 have been made into a histogram as explained in footnote 2. Reasons are advanced in the text for suspecting the extent of the sex differences in mortality in old age shown here.

symphyseal face" (p. 585). She claims that "The rough type first appears clearly in late Phase V or early Phase VI" (p. 585). If this is so, she missed only the sex linkage.

It is strange that attention was not called to these abnormal female pubic symphyses during the more than 30 years between Todd's original description of the phases ('20-'21) and Brooks' critical study thereof ('55). Looking back at Todd's report on females ('21) it is apparent that he underrated the variations which he actually saw. At one point, for example, he found that:

The female White pelves next in order of age are three which form a puzzling group because they present quite diverse features and yet each is of age twenty-five years. They illustrate vividly the extreme difficulty of deducing any conclusions from meager data. Indeed it is only the information which we have culled from the relatively large number of male skeletons which enables us to make use of the female series at all (p. 28).

In spite of such observations—and others could be cited, Todd concluded that "The description of male and female White series shows that both sexes pass through a single definite succession of phases in the metamorphosis of the pubic bone. There are only a few differences in expression of one or two of the phases and these are of relatively minor consequence" (p. 37). Obviously, in view of the evidence, this is a very broad generalization.

Now, abnormalities of the pubic symphysis confined to females must be connected with child-bearing. Quite likely some of the females reaching Todd's dissecting rooms were nulliparas, others were primiparas, and only a few were multiparas, for otherwise there would have been children to claim the bodies. Although we cannot be sure of this, we can be certain that these recent American women present a decided contrast, from the standpoint of reproduction, to the early Indian and Eskimo women, who almost always bore many children, beginning as early as possible. Also, of course,

Indian and Eskimo women led a vigorous existence throughout their pregnancies and received only the most primitive obstetrical assistance. These factors help explain, on the one hand, why Todd was not impressed by the sex differences in the pubis among Whites and Negroes and, on the other hand, why such high frequencies of Phase X types have been reported for American Indian females.

A large medical literature exists on the relaxation of the joints of the pelvis during pregnancy. According to one author (Greenhill, '55, p. 89):

Many women in the later months of pregnancy complain of pain in the pelvic joints, a waddling gait and difficulty in walking. Examination usually reveals tenderness over the pubis, riding of the two bones on each other when the pelvis is strongly rocked from side to side or even a groove showing a larger degree of separation. These changes in the pubis have been demonstrated roentgenographically, there being a symphyseal spread of from 2 to 6 mm in the first half and from 3 to 10 mm in the second half of pregnancy.

Howorth ('52, p. 666, fig. 307) includes this subject in his *Textbook of Orthopedics* under the heading of arthritis, but only through a roentgenogram of the pelvis bearing the legend "Degenerative changes at symphysis pubis following hemorrhage in this area during delivery. Considerable pain and disability. Pathologic examination negative for tuberculosis or tumor." Without going into the evidence in more detail, it is reasonable to expect that frequent pregnancies associated with lack of prenatal care traumatize the pubic symphysis over and over again, with resultant bony degenerative changes. Since some of this information is new, Todd can perhaps be excused for saying, "I do not believe that pregnancy and child-birth leave any permanent stamp upon the skeleton," ('21, p. 40).

It is almost unnecessary to add that the idea here presented is important in age identification. More than ever we need an analysis of a large documented series of female pubes such as McKern ('56) is presenting for males. As Brooks

has shown, and Snow's ('48) data bear out,<sup>3</sup> the cranial sutures are not a reliable substitute. Furthermore, until more reliable pubic age standards are available for females the sex difference in mortality curves for ancient populations will be suspect.

## LITERATURE CITED

- BROOKS, SHEILAGH THOMPSON 1955 Skeletal age at death: The reliability of cranial and pubic age indicators. *Am. J. Phys. Anthropol.*, n.s. 13: 567-597.
- GREENHILL, J. P. 1955 *Obstetrics*. 11th ed. Philadelphia, viii + 1088 pp.
- HOOTON, EARNEST ALBERT 1930 *The Indians of Pecos Pueblo: A study of their skeletal remains*. New Haven, xxvii + 391 pp.
- HOWORTH, M. BECKETT 1952 *A Textbook of Orthopedics*. Philadelphia, xxii + 1110 pp.
- McKERN, THOMAS W. 1956 The symphyseal formula: A new method for determining age from pubic symphyses (Abstract). *Am. J. Phys. Anthropol.*, n.s. 14: 388.
- SNOW, CHARLES E. 1948 Indian Knoll skeletons of site OH 2, Ohio County, Kentucky. *Reports Anthropol. Univ. Kentucky*, 4: (3, II): 367-555.
- STEWART, T. D. 1956 Examination of the possibility that certain skeletal characters predispose to defects in the lumbar neural arches. *Clin. Orthop.*, 8: 44-60.
- TODD, T. WINGATE 1920-21 Age changes in the pubic bone. I. The White male pubis. *Am. J. Phys. Anthropol.*, 3 (3): 285-334; II. The pubis of the White female. *Ibid.* 4: 26-40; IV. The pubis of the female Negro-White hybrid. *Ibid.* 4: 40-70.

---

<sup>3</sup> Snow judged the ages of 260 males and 191 females in the Indian Knoll series from suture closure alone, as follows:

AGE	MALES %	FEMALES %
20-24	29.6	74.9
25-29	24.6	22.0
30-34	16.2	..
35-39	12.7	3.1
40-44	6.5	..
45-49	4.2	
50-54	3.8	
55-59	1.5	
60-64	0.8	

# THE CRANIAL VAULT: FACTORS OF SIZE AND SHAPE <sup>1</sup>

W. W. HOWELLS

*Peabody Museum, Harvard University,  
Cambridge, Massachusetts*

SIX FIGURES

It is surprising that the natural variation in recent human head form — and let us consider particularly the cephalic index — remains a generally uncomprehended phenomenon. Many of the functional explanations offered can only be called fantastic today; and in general these, and phylogenetic explanations as well, fail to give an answer to the really notable differences in this prominent characteristic, especially as between populations of the same racial stock such as the European. Even extreme forms, such as that of the most long-headed Eskimo groups, have not been given any satisfactory explanation, in spite of some celebrated discussion.

There are of course a few provisional hypotheses which the majority of anthropologists would not care to reject. These pertain especially to the variation of individuals within a group, though they may be enlarged upon. For example, the relations of the absolute sizes of the cranial base, of the face and of the brain must be strongly contributing factors, however they may be influenced by special and local supervening

<sup>1</sup> This study was supported by the Research Committee of the Graduate School of the University of Wisconsin, from special funds voted by the Wisconsin State Legislature. Most of the computation was done by the Numerical Analysis Laboratory of the University of Wisconsin, and I am grateful to Prof. C. W. Harris for much help and advice with the form of analysis used. I am also greatly obliged to Dr. G. M. Morant and to Professor Egon Pearson, who permitted me to use, and provided me with, the original data on which the study is based. Appreciation for the drawings goes to Mrs. Henry Ware Eliot and Elmer Rising.



factors of shape. These size factors, which must be basically genetic in origin, may also be modified by functional development, i.e. by the resultants of the operation of different amounts of muscle relating to occiput and jaw. That is to say, a relatively large brain housed above a relatively small skull base will necessarily tend to impart a more globular (rounder) head form to its owner, compared to other individuals of the same population; and similarly, other such trends may follow the size and shape of the whole masticatory apparatus.<sup>2</sup>

All this, however, advances us little, because (a) these are secondary explanations, and (b) the broad range of differences *between* major populations still faces us. We still must find the various local growth determinants which, combining with one another, produce both the continuing differences in head form between racial types, and the range of variation within such a type. The fact that these determinants must be essentially genetic in nature, whatever may be said about accidental deformation of the skull and non-genetic muscular influences on form or contour, is amply indicated by the studies on growth in mammal skulls by Baer ('54), Moss ('54), and others.

In the course of a study of factors of physique generally, the writer (Howells, '51) detected several more or less distinguishable, if not entirely independent, factors of growth of the face and skull, interpreted as one of facial length, one of lateral

<sup>2</sup> These problems and considerations are far from new. Pearson and his associates were working on them at the beginning of the century, in the first volumes of *Biometrika*, and the following quotation from Boas (1899) shows his views:

"The correlation between length and breadth is not an expression of a biological relation between the two measurements, but an effect of the changes which both undergo when the capacity of the skull increases or decreases. The cephalic index, therefore, is not the expression of a law of direct relation between length and breadth of the skull. The proportion between the diameters of the skull and its capacity, on the other hand, expresses an intimate biological relation between these measurements. It appears that the diameters of the head must be considered as due to the tendency of the inner cavity of the skull, or more probably of the brain, to assume a certain size and form in a given type of man, this form being expressed by the proportion of the diameters of the brain and its size." He noted that the correlations of the skull diameters with the cranial capacity far exceeded those among the diameters themselves, and Pearson and coworkers supported this with other findings.



development of the whole head, one of calvarial size associated mainly with length, and one of brain size. These, especially the last two, correspond to the kind of hypothetical growth determinant discussed above. However, this was a relatively crude study, strongly limited by the number and choice of measurements used; and the identification of factors is of course tentative and perhaps, in the case of brain size, dubious. It seemed desirable to explore this aspect further, by using a carefully selected series of human skulls and measuring the brain case in a large number of different ways, to discover if possible some relations of size and shape; and to observe at what points growth or variation tended to be independent of other sites of growth.

#### MATERIAL

Since the best measurements to utilize could not be known beforehand, and since large series are not readily available, it appeared that it would be difficult to improve on certain of the cranial series reported on in the past by workers in the Galton Laboratory of the University of London, using the type contour method of Crewdson Benington ('11).<sup>3</sup> Originally devised to obtain an average outline of a group of crania, as seen in the horizontal, transverse and sagittal planes, the method calls for making an exact tracing of each skull in each of these planes at a given level, upon which tracing a large number of specifically placed diameters are measured. These are, of course, limited to the three particular planes chosen, and an idea of the way in which they actually represent a skull may be seen from figure 4, in which most of the contour measurements are shown diagrammatically. In the English studies they were generally supplemented by a number of the usual cranial measurements, fortunately carefully standardized.

After consideration of several series, that from the ambulatory of St. Leonard's Church, Hythe, Kent, was chosen (Stoessiger and Morant, '32), as furnishing a population in

<sup>3</sup> Modified and supplemented by later workers, e.g. Thomson ('15), Tildesley ('21).

the medium range of the cephalic index, without strongly evident deformation, of European derivation, and numbering over 100; varying furthermore, as judged from the standard deviations of a number of the published measurements, as much as typical series of similar size, and so probably providing the degree of variation in size and shape needed for a useful study. With Doctor Morant's permission, Professor Egon Pearson very kindly sent the writer on loan the original diagrams, or tracings, on which the contour measurements were

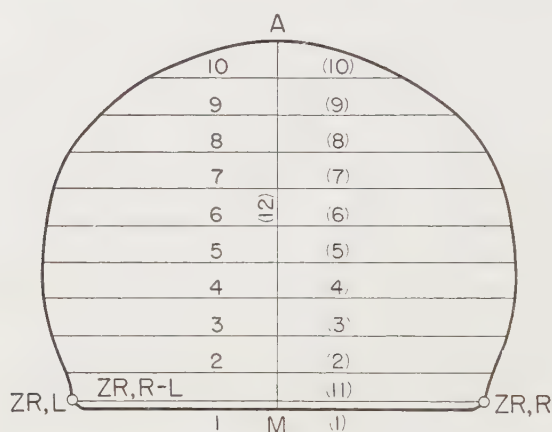


Fig. 1 Measurements on transverse contour. The numerals in parentheses are the identifying numbers of the measurements, as used in this paper; the others are the designations as used in the original source.

recorded. This allowed the use of the original (evidently very careful) contour measurements, not published in the report, and the first hand checking of possible questionable points. It was decided to use the "male" and "probably male" skulls of the series, which numbered 112 altogether. After 54 direct and contour measurements had been selected, the usable crania—those for which all 54 measurements were available—numbered just 100.

These are, of course, measurements relating almost entirely to external contour alone. They are shown in figures 1, 2 and

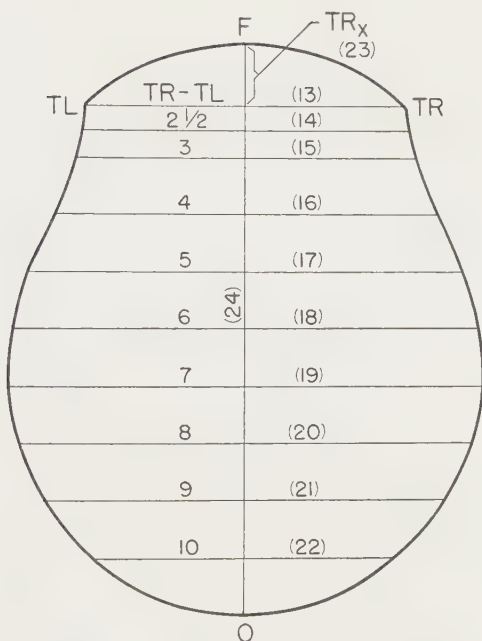


Fig. 2 Measurements on horizontal contour. See legend, figure 1.

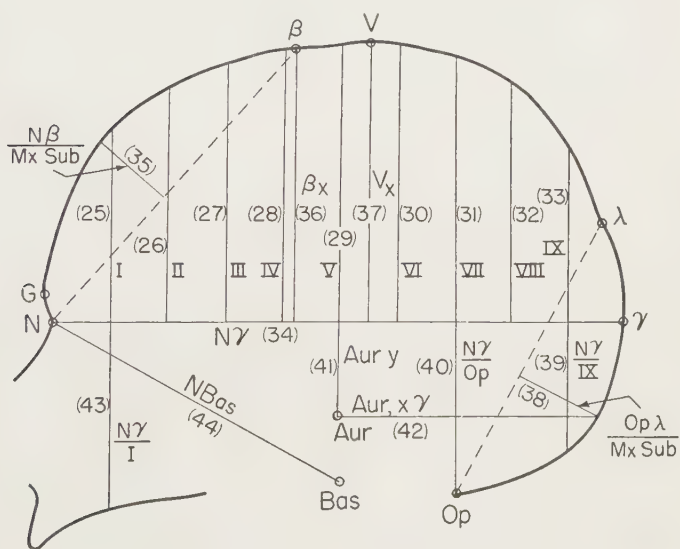


Fig. 3 Measurements on sagittal contour. See legend, figure 1.

3, and are defined below. (The identifying numbers in the figures are those in parentheses.)

Nos. 1 to 12, *Trans 1*, etc. These are all taken from the transverse section, or contour drawing (see fig. 1). No. 1, *Trans 1*, is the horizontal connecting the auricular points, or upper margins of the auricular meatus, also generally termed the poria. No. 12, *Trans MA*, is the vertical from the middle of this line to the apex, and nos. 2 to 10 are

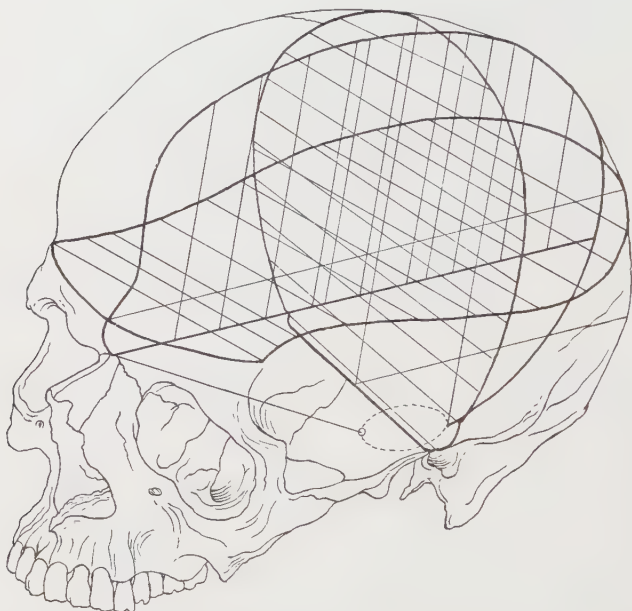


Fig. 4 A rendering of the three contour sections to show their relationships, and the degree to which they represent the form of the skull as a whole. Not all measurements used are included.

horizontals placed at intervals of one-tenth of the distance from M to A. No. 11, *Trans ZR*, is a horizontal joining the intersections of the contour plane with the zygomatic or supra-meatal ridges just above the poria.

Nos. 13 to 24 are on the horizontal section (see fig. 2), which is placed parallel to the Frankfort plane and at the level of glabella, so that its posterior point (O) is not necessarily or normally the terminal of the glabello-occipital length as usually measured. No. 24, *Horiz FO*, is the length in this particular plane. No. 13 is the breadth at the

temporal crests (in this plane), and nos. 14 to 22 are transverses at units of one-tenth the distance FO (no. 14 of course being placed at a half-unit mark). No. 23, *Horiz Tx*, is the distance from F to the TR-TL transverse, and a measure of glabellar protrusion.

Nos. 25 to 44 are measurements from the sagittal section (fig. 3), and are better seen from the figure than described. Most of the verticals (nos. 25 to 33, and 36, 37, 39, 40, 41 and 43) are all measured above or below a base line which is a line through nasion, parallel to the Frankfort plane, whose posterior point is simply its intersection with the occiput, designated "gamma." Nos. 35 and 38 are the greatest depths of the curves of the frontal and occipital bones respectively. No. 44 should correspond well to nasion-basion length measured directly.

The other measurements, 45 to 54, all taken directly, are mostly familiar to craniometry. Their designations appear in several of the tables. No. 46, *IOW*, is "internal biorbital breadth between the points, right and left, where the fronto-malar sutures cross the outer margins of the orbits" (Morant, '31).

#### METHOD

The method is related to factor analysis. Looked on more generally, it is the analysis of the correlations of the measurements, which correlation encompass far more of the total information than do averages of individual measurements, just as averages encompass more than the raw measurements of the individual skulls. In this case, it is simply a search for those particular measurements (read "aspects of cranial development") whose variation appears to be responsible for the variation in all the measurements used. This, with its implications, is the extent of the method. It is something like the following: if one knows the radius of a sphere, one need not measure the diameter, the circumference, or the volume to get further information; here, however, we are not sure of the geometric form to which the skull tends, nor do we know just which particular parameters or measurements will tell us most about the remainder.

A complete table of correlations (table 1, southwest half) was obtained from the 54 measurements in the Numerical Analysis Laboratory of the University of Wisconsin. Ordi-



nary factor analysis would search out the factors, or axes, which would most efficiently reduce or explain all the correlations, and many of these axes would probably be so found as to correspond closely to, or nearly coincide with, actual measurements, and so identify themselves. In this case, the usual method was not applied because (a) analysis of a  $54 \times 54$  matrix involves heavy computation even for IBM equipment, and (b) with so many measurements, it should be possible to identify certain basic factors directly, i.e. they are almost sure to correspond closely to measurements already taken.

The coefficient of correlation measures the degree to which two traits vary together. In factor analysis, as for other purposes, it measures some common, and usually more general, factor of determination. It may be taken also as measuring the influence of each trait upon the other, though without implying either to be the causative element. By the use of partial correlation, the correlation of two traits may be measured after removing the influence of a third trait with which both of them are correlated, and in factor analysis this is essentially what is done: some broad common factor is extracted from the correlations, to determine its nature and effect.

In this sense, a specific, concrete measurement does not differ from an abstract factor, and it might conceivably serve as an efficient estimator of some such general factor. (That is, this would be possible if the measurement actually corresponded closely to some factor, both biologically and in the mathematical "space" created by the correlations of the measurements.) Therefore one might assume that a given measurement was a particularly good "factor," or important as representing some aspect of growth or development, and eliminate its influence from the whole set of correlations, to judge the effect. This is nothing more or less than a "factor analysis" using known or predetermined factors.

This relatively simple method of judging the correlation was used. It was decided to remove length, breadth and

TABLE

Table of correlations and residual

Lower half: original correlations

Upper half: residuals after three factors

Diagonals: communalities, or portion of variance related to ten factors

height as "factors," eliminating not only these evidently important dimensions but also, to a supposedly effective extent, the factor of size itself. This left a matrix of residual correlations (free of any correlation with the first three measurements) which yielded seven further "factors," or measurements representing regions of variation not related to the influence of the first three.

In the terminology and technique of factor analysis, this is equivalent to a group factor method of analysis, extracting several oblique, or correlated, factors together, as distinguished from a centroid, or principal axis solution extracting single orthogonal, or uncorrelated, factors one at a time. Instead of this more usual process, in which reference axes are sought as centroids which automatically find the largest amount of variance, before any assumptions are made as to the nature of these axes or factors, here specific measurements are accepted as reference axes directly, i.e. there is no question of searching and interpreting, but rather of testing the effect on predetermined interpretation — not the query "are factors A, B, and C, to be interpreted as length, breadth, and height," but rather "are length, breadth, and height factors of prime significance, and what else must be considered?" The procedure is not difficult, and is readily handled on IBM equipment. Hand calculation was largely restricted to subtracting the elements of one matrix from another. The steps involved are as follows:

1. Select three measurements.
2. Form  $\Phi$ , matrix of their mutual correlations. Invert.
3. Form S, matrix of correlation of all measurements with the three chosen (columns from total matrix R, southwest half of table 1).
4. Multiply  $S\Phi^{-1} = P$ , a pattern matrix. This gives coordinates placing all other measurements with relation to these "factors." Factorially and geometrically this allows for the fact that the axes of this system are not at right angles to one another (are oblique). Statistically and arithmetically, it removes the effect of the intercorrelations among these three measurements from the main operation, which is removing the influence of these three measurements from the total intercorrelations of all the measurements. P gives the "factor loadings" in one form.
5. Multiply  $PS'$ , or  $S\Phi^{-1}S'$  to give  $R_{1-3}$ , a restored matrix of correlations: i.e. that amount of correlation among all measurements, and of the variance of individual measurements (the diagonal figures, originally 1.000), which is ascribable to the influence of the three



measurements taken as factors. (In the case of these measurements themselves, this is necessarily the total of their variances and correlations.)

6. Subtract  $R_{1-3}$  from  $R$ , the original table of correlations to get the residual correlations after eliminating all correlations due to the three measurements. (In the case of these measurements themselves, all correlations are reduced to .000.)

7. Divide the columns of  $P$  by the square roots of the respective diagonals of  $\Phi^{-1}$ , a process which puts the loadings for all factors on the same scale. These are denoted  $V$  (table 4). They are equivalent to the simple-axis solution of Thurstone ('47). This is the solution for the first three factors.

8. Study the residual matrix for further significant intercorrelations and select further measurements to serve as reference axes or factors. Extraction of these follows the same steps, the following points being borne in mind: (a) the residual diagonals are used, not 1.000; (b) intercorrelations among those axes pertain to this set only, their correlations with the first set being .000, since the correlation related to this set has been entirely removed.

A special advantage of this method of analysis: since the finding of factors is arbitrary and does not depend on the number or particular set of measurements used, the results are not affected if it is desired to discard any measurement at any stage, except for those used as factors, or reference axes.

The set of 54 measurements contains several measures each of length (e.g. 24, 34, 49), breadth (e.g. 5, 19, 48) and height (12, 37, 50). For various considerations, particularly since their mutual correlations (see table 1 or 3) were the lowest of any set of three, the following were chosen: no. 34, sagittal contour nasion-gamma length; no. 19, horizontal contour 7, breadth; no. 50, nasion-bregma height (direct measurement). Taken as factors, the loadings on them of all the measurements are shown in the first three columns ( $V_{34}$ ,  $V_9$ ,  $V_{50}$ ) of table 4. Taken as axes of growth in three dimensions, and thus as determinants of total size, these three account for 50.6% of the variation in all measurements, and for 62.6% of the variation in cranial capacity (the only measure of volume). They account likewise for heavy proportions of the variation in other general measurements: horizontal circumference, 84.5%; transverse arc 70.1%; sagittal arc 67.3%.

TABLE 2

ing after extraction of 10 factors<sup>1</sup>

35	36	37	38	39	40	41	42	43	44	45	46	51	53
379													
	140												
-198	117	195											
...	...	...	523										
171	-105	-167	102	673									
144	-110	-154	...	351	464								
...	...	...	...	...	...	567							
...	...	...	...	...	...	...	237						
114	...	...	...	...	...	160	...	645					
...	...	...	...	...	...	...	-167	129	500				
	...	...	...	...	118	...	...	...	...	269			
...	...	...	...	...	...	...	...	...	...	...	360		
		...	159	195	168	...	...	...	-136	...	173	171	
...	...	...	...	...	...	...	...	...	...	...	...	...	149
122	...	...	...	...	...	131	...	377	...	...	...	...	...

the diagonals) are included.



		12	14	23	27	28	29	30	31
Trans MA	12	248							
Horiz. 2½	14	...	616						
Horiz. TX	23	...	...	426					
Sag III	27	...	...	...	140				
Sag IV	28	...	...	...	127	154			
Sag V	29	115	...	...	115	146	176		
Sag VI	30	108	...	...	104	139	171	207	
Sag VII	31	...	...	...	...	112	138	166	174
Sag VIII	32	...	...	...	...	...	...	118	124
Sag Nas-bregma/Max subtense	35	-111	...	...	-121	-172	-169	-186	-150
Sag Bregma vert.	36	...	...	...	108	123	126	112	...
Sag Vertex vert.	37	120	...	...	107	146	173	192	156
Sag Op-lambda/Max subtense	38	...	105	...	...	...	...	...	...
Sag Nas-gamma/IX	39	...	...	-153	...	-115	-124	-159	-135
Sag Nas-gamma/Op	40	...	...	...	-119	-133	-134	-132	-101
Sag Aur y	41	176	...	...	...	...	...	...	...
Sag Aur x gamma	42	...	...	119	...	...	...	...	...
Sag Nas-gamma/I	43	...	...	...	...	...	...	...	...
Sag Nas-basion	44	...	...	...	...	...	...	...	...
Capacity: C	45	...	...	...	...	...	...	...	...
Int. bi-orbital br: IOW	46	...	...	...	...	...	...	...	...
Sagittal arc: S	51	...	...	...	...	...	...	...	...
Transverse arc: Breg Q'	53	152	...	...	...	...	...	...	...
Nasal ht., left: NH, L	54	...	...	...	...	...	...	...	...

<sup>1</sup> Only residuals larger than .100 are shown, and only those measurements having such residuals (except

The residual correlations (table 1, northeast half) suggested, by localized concentrations, at least 7 further factors, or measurements having significant variation not accounted for by general size, or by growth in any of the three main dimensions. Without relation to possible order of importance, these were the following:

- 9. Transverse contour 9 (high on parietals)
- 11. Transverse contour ZR (basal breadth at poria)
- 13. Horizontal contour TR-TL (across external orbital angles)
- 15. Horizontal contour 3 (region of temporal fossae)
- 22. Horizontal contour 10 (across occiput)
- 25. Sagittal contour 1 (near frontal bosses)
- 33. Sagittal contour 9 (above occiput).

These account for a further 30.8% of the total variance (as found from the sum of the diagonals of the matrix  $R_{4-10}$ ), of the correlation accounted for by their 7 factors without the effect of the first three. They account for only 10.5% of the variance in cranial capacity, which is not surprising if the first three factors are largely accountable for general skull size. The V loadings on these factors are shown in the last 7 columns in table 4.

The final residual correlation (table 2) related largely to measurements of the face, or contour measurements which are not well suited for a study of the present kind, or are otherwise artificial or awkward, as will be noticed later.

#### FACTOR INTERPRETATION

The 10 factors are identical with certain measurements, but seem to have much meaning beyond these measurements alone. Principally, it is indicated that these are the essential measurements out of the whole set, at least as far as the cranial vault is concerned. They may be considered separately.

**V<sub>34</sub>** Apart from being a length factor (with, of course, high loadings in all length measures: no. 24, 34, 42, 49), this seems to be a factor of general size and of "dolichocephaly." It has the largest loadings for cranial capacity, sagittal arc and horizontal circumference, so that absolute size is certainly

involved; it even has positive loadings for breadths in the frontal region, though not in the parietal region. It seems to register dolichocephaly also in its loadings for protrusion of the glabellar region (23) and especially of the inion region (38, 42), as well as in its negative loadings for occipital breadths and lengths (nos. 21, 22, 32, 33), thus strongly suggesting a pointed (lengthened) occiput, but not necessarily a pinched or poorly filled skull. At the same time, the moderate loading for nasion-basion length (no. 44) indicates that the size and length are not so much derived from the skull base as from the general (principally post-auricular) growth of the calvarium.

TABLE 3

*Intercorrelations of factors*

	V <sub>34</sub>	V <sub>19</sub>	V <sub>50</sub>	V <sub>9</sub>	V <sub>11</sub>	V <sub>13</sub>	V <sub>15</sub>	V <sub>22</sub>	V <sub>25</sub>	V <sub>33</sub>
V <sub>34</sub>	1000	016	074	000	000	000	000	000	000	000
V <sub>19</sub>	016	1000	203	000	000	000	000	000	000	000
V <sub>50</sub>	074	203	1000	000	000	000	000	000	000	000
V <sub>9</sub>	000	000	000	1000	-010	223	063	254	217	-016
V <sub>11</sub>	000	000	000	-010	1000	285	220	068	-108	-387
V <sub>13</sub>	000	000	000	223	285	1000	389	121	082	-040
V <sub>15</sub>	000	000	000	063	220	389	1000	-125	230	-312
V <sub>22</sub>	000	000	000	254	068	121	-125	1000	-195	-002
V <sub>25</sub>	000	000	000	217	-108	082	230	-195	1000	207
V <sub>33</sub>	000	000	000	-016	-387	-040	-312	-002	207	1000

**V<sub>19</sub>** This is breadth in the mid-parietal region; it is based upon measurement no. 19 (horizontal contour 7, found six-tenths of the distance from glabella to the occiput in this section), but it corresponds to every measure of breadth of the skull in this immediate region (48, maximum; 4, 5, 18, 20): and all measures of breadth of the skull have significant loadings on it, except those relating to the breadth of the brow-ridges and of the orbital region.

It also is a factor of size (though uncorrelated with V<sub>34</sub>), since it has loadings for capacity, transverse arc and horizontal arc. It also has loadings for all the sagittal heights above the nasion-gamma line (nos. 25-33, 36, 37), and since it

TABLE 4

*Factor loadings of measurements*

	V <sub>34</sub>	V <sub>19</sub>	V <sub>50</sub>	V <sub>9</sub>	V <sub>11</sub>	V <sub>13</sub>	V <sub>15</sub>	V <sub>22</sub>	V <sub>25</sub>	V <sub>23</sub>
1. Trans 1	—05	63	14	00	52	02	00	05	01	—06
2. Trans 2	—05	76	06	—08	46	—04	03	01	05	—01
3. Trans 3	—08	88	02	—01	23	01	04	—06	02	03
4. Trans 4	—02	92	02	06	06	01	05	—05	00	05
5. Trans 5	03	92	02	13	01	04	09	—04	—03	06
6. Trans 6	01	88	04	20	—08	06	08	—01	02	03
7. Trans 7	00	84	03	25	—11	11	05	00	07	00
8. Trans 8	—01	78	—02	43	—04	07	03	01	05	00
9. Trans 9	02	69	—10	66	00	00	00	00	00	00
10. Trans 10	08	52	—16	66	02	02	00	05	—02	—02
11. Trans ZR	01	68	12	00	60	00	00	00	00	00
12. Trans MA	15	34	55	—02	—16	00	00	—10	04	24
13. Horiz. TR-TL	27	21	26	00	00	75	00	00	00	00
14. Horiz. 2½	08	15	—10	08	—01	32	26	—07	—01	03
15. Horiz. 3	19	22	06	00	00	00	78	00	00	00
16. Horiz. 4	28	56	—09	10	—02	—12	54	00	—06	—04
17. Horiz. 5	23	82	—05	06	04	—07	28	—03	—04	02
18. Horiz. 6	13	93	—04	01	02	—01	08	—08	—02	—01
19. Horiz. 7	00	96	00	00	00	00	00	00	00	00
20. Horiz. 8	—14	89	01	04	01	08	—01	17	—01	00
21. Horiz. 9	—17	70	03	07	—01	08	—04	44	—02	00
22. Horiz. 10	—17	40	—02	00	00	00	00	83	00	00
23. Horiz. TX	28	01	18	—04	—03	62	—13	—05	—10	09
24. Horiz. FO	96	08	04	04	03	04	—07	—08	06	08
25. Sag. I	06	26	42	00	00	00	00	00	73	00
26. Sag. II	12	31	48	05	—02	03	—07	—02	59	03
27. Sag. III	11	34	52	04	—02	03	—11	—04	46	12
28. Sag. IV	02	32	57	00	01	01	—13	—07	35	24
29. Sag. V	—05	29	55	—06	—01	—08	—11	—08	32	28
30. Sag. VI	07	26	50	—05	02	—12	—06	—06	27	39
31. Sag. VII	—14	31	40	03	02	—09	—04	—08	24	47
32. Sag. VIII	—25	34	26	04	01	—08	—02	—07	16	54
33. Sag. IX	—28	28	20	00	00	00	00	00	00	75
34. Sag. Nas-gamma	100	00	00	00	00	00	00	00	00	00
35. Sag. Nas-bregma/Max subtense	25	18	06	—02	—03	11	00	13	63	—22
36. Sag. Bregma vert.	—02	37	57	—02	—02	04	—15	—06	32	22
37. Sag. Vertex vert.	—06	27	53	—04	00	—12	—07	—09	27	34
38. Sag. Op-lambda/Max subtense	53	06	04	04	—06	—10	—16	24	28	—20
39. Sag. Nas-gamma/IX	15	—03	02	—13	00	15	—04	33	—16	—22
40. Sag. Nas-gamma/Op	16	—28	20	—09	—02	02	19	24	—31	—24
41. Sag. Aur y	20	—17	—04	15	—11	09	16	—05	—47	—18
42. Sag. Aur. x gamma	83	—20	—04	—10	08	—08	03	03	08	—04
43. Sag. Nas-gamma/I	31	26	—06	11	00	13	04	—06	—29	—15
44. Sag. Nas-basion	35	12	34	17	07	13	00	—14	—38	02
45. Capacity C	47	42	35	12	00	—14	18	07	13	09
46. Int. bi-orbital br. IOW	21	17	13	08	—01	56	04	08	—18	—02
47. Minimum frontal B'	25	24	23	01	00	66	13	04	02	—01
48. Maximum breadth B	03	95	01	06	01	00	01	02	02	02
49. Maximum length L	96	04	04	02	03	04	—03	00	06	—01
50. Basion-bregma ht. H'	00	00	98	00	00	00	00	00	00	00
51. Sagittal arc S	72	09	30	—05	—06	00	—04	10	30	10
52. Horizontal circ. U	77	43	10	06	04	07	12	08	14	—06
53. Transverse arc Breg Q'	21	64	34	19	—19	09	02	—05	06	09
54. Nasal ht., left NH. L	26	15	—04	19	08	12	—02	00	—35	—20



has negative loadings for some of the occipital depths (40, 42) this suggests something relative to the positioning of the nasion-gamma line, i.e. a high placing of the brain case relative to the eye-ear plane. In any event the size element seems to be specifically a matter of brain size — of a ballooning of the parietal part of the cranial envelope — and not of skull size generally (there is a lack of connection with measurements

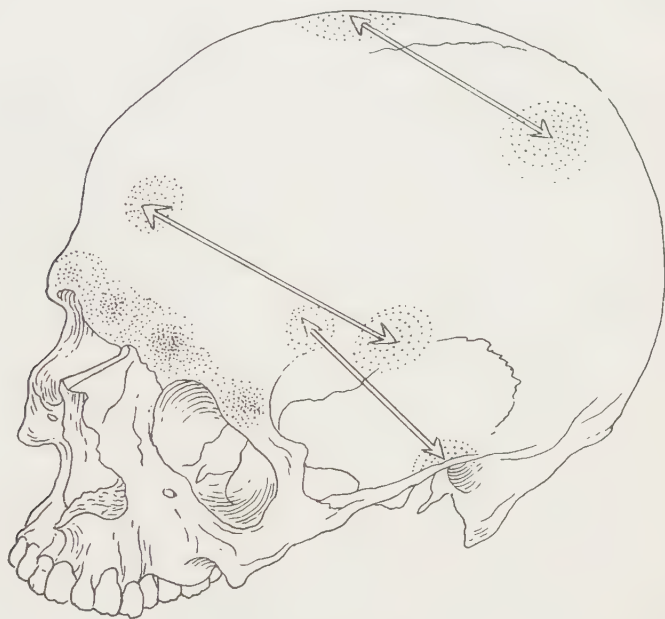


Fig. 5 A pictorial suggestion of the areas of variation in form located by factors  $V_{13}$ ,  $V_{15}$ ,  $V_{11}$  and  $V_9$  (brow development, breadths at temples, at poria, and lateral to apex).

like biorbital or nasion-basion and there is a small negative loading for the post-auricular length, no. 42). In a way, this might be looked on as a factor of "brachycephaly," although the suggestion needs amplification.

$V_{50}$  This is of course a factor of height, but it is difficult to say much about it. It relates to heights above the nasion-gamma line, especially in the region of bregma, and reflects more a raising upward of the frontal region than of any other

part. The surprising thing is that it does not register a downward expansion of the vault (nos. 39, 40, 41) although it is based on nasion-bregma height (no. 50, as distinguished from heights above a longitudinal base line, cf. nos. 12, 37). It has the third largest loading given by cranial capacity; nevertheless it has no spectacular loadings. It is an unspecific factor

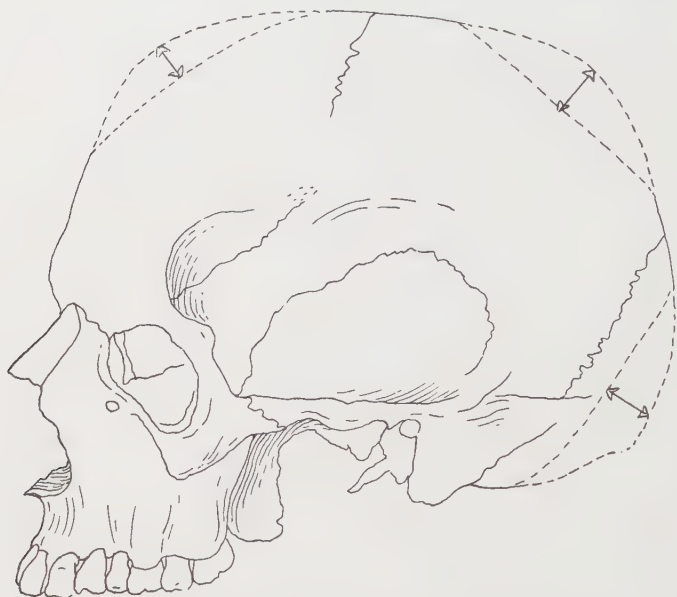


Fig. 6 A pictorial suggestion of the areas of variation in form located by factors  $V_{25}$ ,  $V_{22}$  and  $V_{33}$  (fullness or lack at forehead angle, at obelion, and across occiput).

of (brain) size, alternative or supplementary to that of breadth (with which it is only slightly correlated).

$V_9$  This is a factor of breadth at the apex of the skull, i.e., the antithesis of "keeling" in this region; it has an insignificant correlation with cranial capacity. It is thus supplementary to  $V_{19}$ ; it is of course completely uncorrelated with the latter (see table 3) and thus independent of it.

$V_{11}$  Like the previous factor, this is local: breadth at the base of the skull. It is completely independent of  $V_{19}$ , and also of  $V_9$  (see table 3).

**V<sub>13</sub>** This interesting factor (based on horizontal contour TR-TL, the breadth across the frontal angles) evidently represents the bony brows, both for lateral growth and for forward growth (cf. no. 23). It is the principal, and the essential, determinant of minimum frontal breadth (no. 47) and, in this set of measurements, of internal biorbital width (no. 46). It has an appreciable though not large correlation with V<sub>15</sub>, the frontal breadth a short distance behind it. Evidently it is a better measure than minimum frontal, since the former, not the latter, emerges from the analysis as an appropriate factor, i.e. this measurement or factor determines minimum frontal rather than vice versa. Nonetheless, this is a factor of the facial skeleton more than of the cranial vault. (It has a negligible *negative* loading for cranial capacity.)

**V<sub>15</sub>** This is a factor of the breadth of the forebrain in the temporal fossa, somewhat correlated with the breadth or size of the brows, V<sub>13</sub>, but uncorrelated with other breadths, and having the fourth largest (though very small) loading for cranial capacity. It has a negligible loading for minimum frontal. This factor evidently is concerned with an area of variation not usually measured on the skull.

**V<sub>22</sub>** This apparently registers a fullness of the occipital region, expressing horizontal breadth here, and also depth (nos. 39, 40) and to some degree protrusion of the lower portion (no. 38; inion as against opisthocranion). However, since measurement no. 22 itself has a small negative loading on V<sub>34</sub>, length, the fullness may be partly a compensatory fullness, that is, a reflection of slight degrees of accidental deformation or flattening.

**V<sub>25</sub>** This is a factor of frontal fullness, being the third factor (in addition to V<sub>19</sub> and V<sub>50</sub>) to have loadings for frontal heights and having the one high loading for no. 35, the frontal subtense or forehead bulge. It has substantial negative loadings (the only factor to show such) for occipital depths, for basion-nasion length, and for facial height. All of this suggests that it is a factor of shape, not size, and reflects

a crowding forward of the brain toward the frontal region, particularly in small-faced skulls (recalling women, infants, and pygmies).

$V_{33}$  This is a factor similar in character to  $V_{25}$  but different in location: it is a vertical fullness but in the obelionic and lambdoid region. It, like  $V_{25}$ , has (small) negative loadings for lower occipital depths, for facial height, for forehead fullness, no. 35; and negative correlations with factors  $V_{11}$  (breadth of skull base) and  $V_{15}$  (breadth of fore brain); and its important measurements (nos. 32, 33) have negative loadings on  $V_{31}$ . Accordingly, it seems to be a factor of general lambdoid fullness in otherwise smallish skulls, being an alternative or compensatory development to forehead fullness.

#### GENERAL INTERPRETATIONS

The preceding interpretations are not easily digestible, and of course highly tentative. More generally, the results seem to be as follows. At least ten factors are visible, all more or less independent of one another (table 3). They are in no sense *types*; they are tendencies expressed in all skulls to varying degrees, mutually determining the size and shape of individual skulls in this series.

The first three are contributors to size of the cranial vault, through general head size and length, through size and lateral expansion of the brain proper, and through general upward development and filling out of the sagittal vault region. The first two factors between them probably largely determine what is measured by the cranial index.

The other seven factors do not influence size so much as details of shape (since they account for about 30% of variance in specific local measurements other than the principal length, breadth and height, but for only 10% of variance of the volume): they seem to constitute regions of adjustment of particular importance, corresponding entirely with zones and impulses of growth observed in experimental studies, with the resultant of all of them being the particular skull form of indi-



viduals. Thus this kind of analysis may be looked on as complementary to such growth studies, since it would be quite impossible to attack all the special kinds of variation in human skull form directly by *in vivo* studies. These seven factors are: variation in supraorbital development, in forebrain width, in forehead fullness, in obelionic fullness, in fullness across the top of the parietals, in lower occipital fullness, and in basal (biauricular) breadth. Nothing may be said about causation: these are simply the localities of variation. It may be supposed that supraorbital and basal breadths are specifically skeletal in determination, while the others are local responses to cerebral growth, and also probably to accidental modification through "deformation."

*Deformation.* Doubtless any human population is exposed to slight degrees of accidental flattening of the back, especially, of the head. This cause of variation might be expected to manifest itself in the figures, and so it seems to do. The factor  $V_{22}$ , for breadths across the occipital pole, may register variation in these breadths simply because of flattening. Similarly, the variation in heights higher up on the occiput, expressed by  $V_{25}$ , may be the result of flattening through deformation, or correspond to the unexplained peculiarity known as "lambdoid flattening."

*Cranial capacity and brain size.* In the first place, the figures provide a comment on the estimation of internal volume from external measures of the vault. The ten factors, or measurements, which explain virtually all the correlation and variation of the other measurements of the vault (not of the face, nor of basion-nasion length) account for a large but lesser amount of the variation in cranial capacity (73%, of which 62.6% is related to length, breadth, and height alone). Without reviewing the details, this seems to mean that formulae for estimation using the usual external diameters and circumferences, even when taking account of measurements not usually included, e.g. forehead arcs, are unlikely to improve substantially in accuracy beyond the point they have

already reached, due to variations in special regions (particularly the anterior and middle cranial fossae).

A second, more immediate, problem is whether any of the factors found is principally an expression of brain tissue growth, as distinct from size resulting from skeletal growth, whether alone or in local adjustment to brain size. I have suggested above that this is the nature of  $V_{19}$ , the parietal breadth factor. In a previous study (Howells, '51) of living subjects two principal head factors were found; one, related mainly to length, but also to breadth (denoted  $V_9$  in that study), was taken to express skeletal cranial size, and one ( $V_{10}$ ), related to breadth and somewhat to height, was identified, with misgivings, as expressing brain size in the sense just described. These tentative identifications were in fact the reason for the present study. The question, therefore, is whether a similar result appears now: whether factors found here correspond to those found before, especially in expressing cranial (skeletal) size vs. brain size.

It is evident from inspection that the patterns of loadings (see table 5) in the two studies do not correspond directly, factor for factor. This is not surprising, however, since the factors in each case are simply relatively arbitrary reference axes, not necessarily placed in the same positions and thus not necessarily reflecting correlation and variation identically; furthermore, the present study has a separate height factor ( $V_{50}$ ) contributing to size, which was not present (evidently included in the "length" and "breadth" factors) in the first study.

The answer to be sought is therefore a mathematical one, corresponding to the mathematical question: Is there a matrix which will transform the one set of factors consistently into the other, thus showing that they are related?

Such a matrix,  $X$ , if it exists, may be found by taking  $A$  as the first group of factors,  $B$  as the second group, and finding  $X$  as  $(A'A)^{-1} A'B$ . Then  $AX = B$ . (Table 5 shows the loadings of all the vault measurements common to both studies, unfortunately few.) Under  $A$  are the loadings for  $V_{34}$ ,  $V_{19}$  and  $V_{50}$  of the present study from table 4; under  $B$  are the loadings for  $V_9$  and  $V_{10}$  of the previous study;

under  $X$  are the values needed for the multiplication  $AX$  (row by column) to produce the expected approximations to  $B$ ; under  $AX$  are shown these approximations.

TABLE 5  
*Transformation of factor loadings*

		$A^1$			$B$		$AX$	
		$V_{34}$	$V_{19}$	$V_{50}$	$V_9$	$V_{10}$	$AX_9$	$AX_{10}$
52	Head circumference	.772	.431	.102	.80	.42	.88	.33
49	Head length	.964	.039	.043	.84	.00	.83	.05
48	Head breadth	.034	.951	.006	.41	.61	.38	.62
50	Head height	.000	.000	.977	.54	.48	.52	.46
47	Minimum frontal	.252	.235	.225	.33	.16	.41	.26

$X$	
$X_9$	$X_{10}$
.793	.000
.369	.653
.536	.475

<sup>1</sup> Values of loadings given to three places of decimals for precision in computation; they have been reduced to two places in table 4.

The correspondence between the appropriate columns of  $AX$  and  $B$  — between two studies on different populations, one living and one cranial — is good, and seems to assure us that the same relationships, whatever they may be, are being expressed. This prompts us further along the same line. Table 6 deals with other (cranial) measurements not available in the previous study. Under  $A$ , once more, on the factor loadings (as in table 5) for  $V_{34}$ ,  $V_{19}$ ,  $V_{50}$ , and under  $AX$  the estimated loadings for  $V_9$ ,  $V_{10}$  of the other study, i.e. what these factors might have shown for the measurements involved had they been available.

These are interesting results. On first viewing them I was inclined to feel that the identification of  $V_{10}$  as a brain factor had been an unfortunate one, since it has far less to do with cranial capacity than has the size (length) factor,  $V_9$ . On second thought, however, all the results seem to be consistent.

In this hypothetical extension,  $V_{10}$  of the former study has lower loadings everywhere than  $V_9$ , its important ones being parietal breadths. It has a good loading for capacity, but is greatly exceeded in this by  $V_9$ . This latter has a much larger loading in table 6, in fact, for capacity than has any factor in the present study; and the same is true for its loading for nasion-basion length, as representing the skull base. Taking

TABLE 6  
*Transformed factor loadings for various measurements*

		<i>A</i>			<i>AX</i>	
		$V_{34}$	$V_{19}$	$V_{69}$	$AX_9$	$AX_{10}$
45	Cranial capacity	.468	.424	.346	.71	.44
44	Basion-nasion	.350	.125	.339	.51	.24
11	Biauricular breadth	.009	.682	.125	.33	.50
53	Transverse arc	.209	.637	.345	.59	.58
8	Trans 8 (breadth above parietal bosses)	— .012	.782	— .016	.27	.50
33	Sag IX (occipital depth)	— .280	.276	.195	— .02	.27
23	Horiz TX (glabellar projection)	.283	.014	.180	.33	.10
35	Nasion-bregma subtense	.250	.183	.059	.31	.15

both studies together, then, their two sets of factors, or reference axes, project the same information somewhat differently, as follows. In the present study, size is distributed more evenly among three factors related to the three main diameters or dimensions; however, length is predominantly connected with actual skeletal size, breadth with grain tissue, and height with undifferentiated space. In the previous study, on the other hand, the "length" factor ( $V_9$ ) is a much broader one of general skull size, including brain size, while  $V_{10}$  is much more specifically one of brain size not only independent of, but antithetical to, general size, i.e. the expression in skull shape of brain size when skull size is diminished. This possibly difficult distinction is strongly supported by the fact that, in the previous study,  $V_{10}$  had a high *negative* correlation, as a factor, with  $V_9$ ; that is, instead of being independent,  $V_{10}$  is



stronger as  $V_9$  is weaker, or brain size is more strongly expressed as general skull size is less influential. As for the undifferentiated space of the height factor in the present study, this is distributed between "size" and "brain" in the 1951 analysis.

#### CONCLUSIONS

It must, of course, be remembered that the placing of factors, as reference axes, is arbitrary; and whether the placing of the main factors in this study is more informative than in the other, or whether some other intermediate system would be better, is a question. The general information, however, seems to be the same: it is not unknown material, of course, but is expressed here as the analysis of the variation of a number of adult skulls, not as the analysis of growth, observed directly or experimentally. There are two distinct forces, the growth of the skull itself as a platform and envelope for the brain (and jaws), and the growth of the brain as a mass of tissue; there is nevertheless some positive correlation between them, but exactly how much cannot be said here, since the factors cannot be precisely identified with either. Growth of the skull *itself* tends to be produced in an anterior-posterior direction, and growth of the brain in a transverse direction, though there is a high flexibility in an upward direction (i.e. there appears to be fluctuation in vertical growth independent of either — a separate height factor). The joint effect of the first two factors, particularly, must determine general form (dolichocephaly vs. brachycephaly). Beyond this are secondary points of adjustment to size and probably to muscle pull, as well as to inherent growth (e.g. brow ridges) where the vault responds to various forces and genetic factors and modifies further not only its "cranial index" but also its specific shape, producing such distinctions as have been recorded by systems like Sergi's. These systems of course are only conventionalized ways of stating whether the frontal region is narrow relative to the supraorbital ridges or to the parietal region, etc. etc.

The result of this study is simply a new vantage point for viewing long discussed matters, as well as the massive amount of data already existing on the cranial vault. Having begun with the idea that radically different suggestions as to how to measure the vault might emerge, I was a little surprised to find that length, breadth, and height, as major and independently significant measures, were not bad selections after all.<sup>4</sup> Probably measuring length from nasion rather than glabella would be better, not so much because the nasion-gamma length seems the best factor in this particular study as because of the independent variation of size in the supra-orbital region (as  $V_{13}$  above). Evidently, minimum frontal diameter has been a poor choice, and it would have been better to use a supraorbital breadth, and also some measure of frontal breadth behind the minimum frontal, and free of the influence of supraorbital development. Certain other measures of fullness of the frontal and occipital bones, and of the parietals near the apex, seem significant. With these, the general form and size of the vault would seem to be adequately and accurately described for familiar craniometric purposes, such general measures as arcs and circumferences conveying no further information. However, cranial capacity is probably best measured directly, since it has a respectable variation independent of the ten main measurements distinguished in this study.

It would be interesting to know whether these measurements could be improved on further, as the most significant parameters of skull size and form; whether they would appear as

<sup>4</sup> It should be objected that these were arbitrarily selected as first factors, and that the three contour planes in which most of the measurements employed lie would, at least, have strongly suggested this selection. The answer is (a) that these three measurements have very low intercorrelations (which of course might not be equally true of other cranial series), and (b) study of possible rotation of these factors to better positions after their original location did not suggest any substantial improvements in significance, and it was decided to leave them identified with specific diameters; the most likely change would have been rotation of  $V_{34}$ , length, to a position corresponding more to general size, and thus producing something like the factor  $V_9$  in the previous study (see above, and Howells, '51). For further comment see the appendix.

equally significant in other cranial populations; and whether they would serve as the most useful characters in intergroup comparisons, i.e. for taxonomic purposes.

#### SUMMARY

An analysis has been made of 54 measurements taken on 100 male skulls (the Hythe series) to determine which of this set of measurements are the most significant and independent variates: whether there are certain ones which will explain the variation of the whole set, and how many such there may be. The method is an analysis of the correlations, by removing the influence of, or partialing out, the correlation of certain measurements which give evidence of being important and independent of one another. It is found that 10 measurements account for virtually all of the correlation in the cranial vault proper. Three of these, corresponding to length, breadth, and height, account for much of the variation, especially in general size. Seven others relate to smaller but significant variation in specific regions: the supraorbital ridges, forehead breadth, height, account for much of the variation, especially in general parietals, height of the obelionic region, fullness of the lower occiput, and breadth of the base at the auricular meatus. Suggestions are made as to the relative worth of various measurements in conventional studies.

#### APPENDIX

The following may be informative to those interested in factor analysis of physical form, and particularly in the nature of "general factors." Table 7 shows, in the first column, the first "centroid" factor which would result from the usual analysis of this kind. This at first seems "general," but is actually, as should be expected, heavily saturated on the measurements which are at once most numerous and most highly intercorrelated, those of breadth; it therefore is a function of the selection of measurements and should in no wise be looked on as "general."

The next three columns are orthogonal factors, i.e. uncorrelated factors derived not by a direct solution but by the multiplication  $S\sqrt{\Phi^{-1}}$ , or matrix S (columns 34, 19 and 50 from table 1) postmulti-

TABLE 7  
First centroid factor, and orthogonal factors

	FIRST CENTROID	ORTHOGONAL			
		I	II	III	h <sup>2</sup>
1. Trans 1	.618	.465	.092	-.499	.474
2. Trans 2	.670	.497	.190	-.583	.623
3. Trans 3	.758	.535	.259	-.689	.828
4. Trans 4	.815	.597	.296	-.676	.901
5. Trans 5	.845	.621	.307	-.643	.893
6. Trans 6	.844	.598	.268	-.629	.825
7. Trans 7	.832	.560	.261	-.602	.744
8. Trans 8	.781	.486	.275	-.567	.633
9. Trans 9	.681	.395	.318	-.466	.474
10. Trans 10	.523	.277	.326	-.301	.274
11. Trans ZR	.672	.525	.137	-.493	.537
12. Trans MA	.655	.664	-.266	-.193	.549
13. Horiz. TR-TL	.600	.473	-.040	.017	.226
14. Horiz. 2½	.252	.083	.161	-.037	.034
15. Horiz. 3	.417	.300	.097	-.027	.100
16. Horiz. 4	.589	.481	.356	-.193	.395
17. Horiz. 5	.777	.639	.394	-.418	.738
18. Horiz. 6	.816	.650	.397	-.572	.907
19. Horiz. 7	.814	.630	.334	-.701	1.000
20. Horiz. 8	.745	.489	.245	-.735	.839
21. Horiz. 9	.612	.366	.156	-.623	.546
22. Horiz. 10	.324	.133	.097	-.400	.187
23. Horiz. TX	.298	.304	-.042	.173	.124
24. Horiz. FO	.449	.682	.317	.610	.938
25. Sag. I	.606	.474	-.226	-.179	.308
26. Sag. II	.695	.585	-.236	-.181	.431
27. Sag. III	.716	.624	-.263	-.218	.506
28. Sag. IV	.661	.589	-.336	-.266	.531
29. Sag. V	.566	.511	-.351	-.291	.469
30. Sag. VI	.504	.444	-.329	-.276	.382
31. Sag. VII	.488	.371	-.251	-.358	.329
32. Sag. VIII	.413	.227	-.173	-.442	.276
33. Sag. IX	.302	.127	-.155	-.413	.211
34. Sag. Nas-gamma	.353	.630	.334	.702	1.001
35. Sag. Nas-bregma/Max subtense	.394	.314	.099	.039	.110
36. Sag. Bregma vert.	.679	.595	-.329	-.328	.570
37. Sag. Vertex vert.	.528	.482	-.344	-.286	.432
38. Sag. Op-lambda/Max subtense	.284	.400	.169	.329	.297
39. Sag. Nas-gamma/IX	.004	.089	.020	.126	.024
40. Sag. Nas-gamma/Op	-.163	.047	-.201	.297	.131
41. Sag. Aur y	-.119	-.010	.034	.266	.072
42. Sag. Aur x gamma	.079	.371	.244	.728	.727
43. Sag. Nas-gamma/I	.376	.328	.236	.033	.164
44. Sag. Nas-basion	.371	.520	-.108	.124	.297
42. Sag Aur x gamma	.079	.371	.244	.728	.727
46. Int. bi-orbital br. IOW	.416	.324	.026	.017	.106
47. Minimum frontal R'	.608	.456	-.013	-.012	.208
48. Maximum breadth B	.838	.637	.331	-.657	.947
49. Maximum length L	.427	.661	.303	.646	.946
50. Basion-bregma ht. H'	.490	.630	-.771	-.092	1.000
51. Sagittal arc S	.557	.706	.041	.415	.672
52. Horizontal circ. U	.783	.830	.325	.224	.845
53. Transverse arc Breg Q'	.889	.764	.015	-.342	.701
54. Nasal ht., left NH. L	.174	.240	.167	.078	.092
TOTALS	Sum of squares 29.1	Sum, squares 13.8	Sum, squares 3.7	Sum, squares 9.7	Sum 27.2



plied by a matrix which is a root of the inverse of the matrix of inter-correlations of these measurements or factors (obtained by factoring completely the matrix involved).

This in effect removes the obliquity of the original factors related directly to length, breadth, and height. Notice that it produces a first factor which is placed centrally to the original ones (has equivalent loadings for 19, 34, and 50), and is thus a better "general" factor than that in the first column. The latter (foot of table) accounts for approximately 29/54 of the total variance of the measurements (mostly breadths) but for only .57 of the variance of cranial capacity (.754)<sup>2</sup>; whereas the first orthogonal factor of this transformation accounts for only about 14/54 of the total variance but for about .63 of the variance of cranial capacity. It accounts for somewhat more of the total variance of the three cranial arcs (nos. 51, 52 and 53) as well: .59 versus .57.

Therefore a first or general factor of the centroid or principal axis type may, in a case like this, conceal more than it reveals; taking it automatically as a factor of general size is not safe. The first, or "general" factor generated from the first three oblique factors is evidently more meaningful, as we have seen, certainly if it accounts for more of the cranial capacity.

This orthogonal matrix of three factors gives, instead of the specific kind of factor from which it was derived, a general factor of size followed by two of the usual kind of bipolar factor: one for height opposed to length and breadth together (or a high versus a spread-out skull) and the other for length versus breadth. These two are evidently factors of shape, not of size; the capacity does not register on them at all, but only on the first; the same is true of forehead breadths, and of basion-nasion length; and the cranial arcs behave just as would be expected.

#### LITERATURE CITED

- BAER, MELVIN J. 1954 Patterns of growth of the skull as revealed by vital staining. *Human Biology*, 26: 80-126.
- BENINGTON, R. CREWDSON 1911 Cranial type-contours. *Biometrika*, 8: 123-201.
- BOAS, FRANZ 1899 The cephalic index. *Amer. Anthropologist*, n.s. 1: 448-461.
- FAWCETT, CICELY D. 1902 A second study of the variation and correlation of the human skull, with special reference to the Naqada crania. *Biometrika*, 1: 408-467.
- HOWELLS, W. W. 1951 Factors of human physique. *Am. J. Phys. Anthropol.*, 9: 159-192.

- MORANT, G. M. 1923 A first study of the Tibetan skull. *Biometrika*, 14: 193-260.
- 1931 A study of the recently excavated Spitalfields crania. *Biometrika*, 23: 191-248.
- MOSS, MELVIN L. 1954 Growth of the calvaria in the rat. The determination of osseous morphology. *Am. J. Anat.*, 94: 333-362.
- STOESSIGER, BRENDA N., AND G. M. MORANT 1932 A study of the crania in the vaulted ambulatory of Saint Leonard's Church, Hythe. *Biometrika*, 24: 135-202.
- THOMSON, EVELINE Y. 1915 A study of the crania of the Moriori, or aborigines of the Chatham Islands, now in the Museum of the Royal College of Surgeons. *Biometrika*, 11: 82-135.
- THURSTONE, L. L. 1947 Multiple-factor analysis. A development and expansion of The Vectors of Mind. University of Chicago Press. 535 pp.
- TILDESLEY, M. L. 1921 A first study of the Burmese skull. *Biometrika*, 13: 176-262.

# A COMPARISON OF SPLIT-LINE PATTERNS IN THE SKULLS OF A JUVENILE AND AN ADULT MALE GORILLA

N. C. TAPPEN

*Department of Anatomy, Emory University*

TWO FIGURES

The split-line technique for analyzing compact bone organization has been applied mainly to adult forms. As a consequence, little is known of the extent to which patterns of organization change with development of the individual in different species. Ahrens ('36) showed that the well-defined infantile patterns in the human cranial vault disappear during childhood. Seipel ('48) demonstrated a complete breakdown of split-line organization of alveolar bone around the erupting permanent canine tooth of a subadult chimpanzee. His younger chimpanzee specimens show the same high degree of organization along the axis of this tooth observed by Henckel ('31) and Tappen ('53) on adults.

These limited observations indicate that split-line patterns of the skull can be affected during development of the individual. The application of the technique to problems of development in the skulls of other primates therefore offers promise of adding to knowledge of the organization and reorganization of Haversian systems during growth, and may give information on the processes of change in form resulting from individual development.

A previous paper (Tappen, '54) reported split-line patterns in the skull of a juvenile gorilla as part of a series of preparations on non-human primates. An adult male gorilla skull was later made available for processing. This article compares patterns in the juvenile and adult forms.

The project was aided by a grant from the Wenner-Gren Foundation.

#### MATERIAL AND METHODS

The juvenile gorilla skull was donated by Mr. Harold Green of the Philadelphia Academy of Natural Sciences. Only the first permanent molars are erupted. The sex is not known. The adult male gorilla skull was loaned by the Peabody Museum through the courtesy of the late Dr. E. A. Hooton.

Both skulls were damaged by bullets. The greater part of the right half of the face of the juvenile was destroyed. The adult specimen suffered damage to the mandible and the zygomatic region of the left side. The left canine tooth of the adult skull had been removed after death. The alveolus was not damaged.

The split-line technique was devised by Benninghoff ('25). When compact bone is partially decalcified in dilute acid it is soft enough to be punctured by a needle or an awl. In many areas of both flat and long bones these punctures form short splits rather than round or irregular holes. According to Benninghoff and Seipel ('48), these splits follow the direction of orientation of a majority of the Haversian systems in the area punctured. Ink is inserted into the splits to make them easily visible and to obtain a permanent record.

Earlier workers made intermittent punctures and derived the general direction of orientation of the splits. Seipel ('48) introduced the technique of making the splits continuous, giving a clearer picture of the general orientation of the Haversian systems in different parts of the facial skeleton, and allowing a better delineation of the transitional zones between divergent systems of split-lines. This must be done with caution, however. While some regions give very clear and continuous splits, others are not so highly organized or have no apparent orientation. It is possible to make continuous though irregular lines in decalcified bone of this hyaline character, especially if it is very thin. It is therefore neces-



sary to make discontinuous punctures in an unexplored bony surface and to maintain this procedure if a definite direction of splitting is not repeatedly produced. On the other hand, it is not possible to force the needle in a direction away from that of the general orientation if the bone is even moderately well organized.

#### OBSERVATIONS

The maxillary regions of both specimens show (fig. 1) the ascending pattern of split-lines observed in human and other primate skulls. The juvenile does not have the lines paralleling the alveolar margin and at right angles to the



Fig. 1 Split-line preparation of adult and juvenile gorilla. General aspect.

ascending maxillary lines observed in the adult specimen, except above the erupted first permanent upper molar tooth.

In the adult gorilla, lines ascending from the canine tooth area deviate laterally inferior to the orbit. The more medial of these lines deviate at a higher level, tending to become confluent with lines circumscribing the orbit. The more lateral and posterior lines cross over at a lower level and turn back downward toward the border of the region of origin of the masseter muscle. Because of bullet damage, they can be demonstrated only on the right side. They run parallel to lines taking a continuous course from this area along the lateral orbital region, across the frontal torus, and down to the zygomatic region of the opposite side. Laterally and superiorly on the brow ridge the bone has no split-line organization, only irregular holes resulting from the needle punctures. The bone in this area was somewhat roughened and pitted at the surface, similar in texture to thickened areas of bone lacking split-line structure in other primates (Tappen, '54).

The young gorilla shows little of the lateral deviation of ascending lines above the canine tooth. In the molar region the split-lines traverse laterally along the zygomatico-alveolar crest. The lines in the zygomatic region terminating at the location of the attachment of the anterior tendinous portion of the masseter muscle are much less extensive than in the adult. They form a small area which separates the lines in the maxilla from those running parallel to the orbit, tending to run at right angles to the former and to converge with the latter. In the frontal bone behind the developing brow ridges the lines are generally oriented in an anterior-posterior direction. These lines are continuous into the brow ridges, where they deviate medially before terminating at the orbital boundary. More laterally in the supraorbital region the lines are almost parallel to the orbital margin, passing along the area which shows no split-lines in the adult specimen. The lines in the more medial part of the lateral orbital region are part of a circum-orbital system, while the more lateral lines course parallel to the lateral margin.

The anterior-posterior lines in the young gorilla frontal bone terminate at the fronto-parietal suture. The lines in the adjacent part of the parietal bone course approximately at right angles to this orientation. They are continuations of lines which radiate in the area bounded by the temporal muscle, having the same general course as its contiguous fibers. The temporal lines mark the boundary at which the noticeable



Fig. 2 Split-line preparation of juvenile and adult gorilla. Superior aspect.

deviation in direction between these two patterns takes place, as shown in figure 2.

The split-lines in this area are substantially different in the adult gorilla, being generally irregular and poorly defined. Mastoid air cells have invaded the lower part; the very thin cortical bone covering them gives no evidence of split-line organization. Immediately above, many of the split-lines course in a direction approximately at right angles to those of the juvenile gorilla, as shown in figures 1 and 2. Only the sagittal crest shows split-lines parallel to the presumed direction of pull of the adjacent temporal muscle fibers.

The split-lines in the mandible are very similar in the two specimens, except that the young gorilla does not have a pattern of lines running parallel to the mandibular notch. Split-lines inferior to the canine and incisor teeth are more irregular in direction in the juvenile specimen than in the adult.

#### DISCUSSION

The most striking gross changes from the juvenile to the adult condition in the gorilla skull are the development of the great supraorbital torus and sagittal crest. Another large difference is the spacial separation that has arisen between the facial and braincase portions in the adult, illustrated particularly in figure 2. These changes are accompanied by differences in split-line patterns.

The continuous split-lines in the adult brow ridge are not duplicated in the juvenile specimen, but there are indications of a transition from an earlier pattern of lines in the frontal bone toward the adult condition. It is believed that the temporal muscle causes the lateral deviation of split-lines which appears to be in process of formation in this specimen.

The zygomatic area of split-lines, probably associated with pull from the masseter muscle, is quite small in the young specimen. It appears to be encroaching upon the areas of



circumorbital and maxillary split-lines, indicating that a change toward the adult condition is taking place in another area.

Split-lines at the lateral boundary of the lateral orbital region in the young gorilla are not continuous with those in the area of origin of the masseter muscle, as is the case with the adult specimen. The predominant feature here is the system of circumorbital lines. These maintain their integrity in the adult gorilla, but the split-lines which are continuous with the zygomatic region occupy a relatively greater area of the lateral orbital region. Once again, the young gorilla appears to show a transition toward the adult condition from an earlier pattern, although the change has not advanced so far as in the supraorbital and zygomatic regions.

In the three areas discussed above, the changes in split-line patterns are believed to be brought about primarily by the action of chewing muscles. The adult patterns show the effect of muscle action more clearly, presumably because of the longer period of time the muscles have been exerting force on the bone, and because the muscles are stronger. The very opposite seems to be the case in the area of the skull covered by the origins of the temporal muscle, where there is a partial loss of an earlier pattern that was quite clearly defined. A close study of the attachments of the temporal muscle in the gorilla should be relevant to this problem.

The absence of a pattern of lines coursing parallel to the mandibular notch of the young gorilla is similar to the condition in the mandible of a juvenile chimpanzee reported by Seipel ('48). All mature primates processed by Tappen ('54) showed the pattern clearly. The reason for its development is not understood.

The differences between the split-line patterns in the juvenile and adult gorilla skulls described here are substantial, indicating that notable changes in Haversian system organization take place during growth. In several regions the young specimen shows patterns that are interpreted as being tran-

sitional from an earlier organization toward the adult condition. A larger number of specimens of different ages are needed to find out if these inferences are correct or whether the patterns observed are individual variations. If they turn out to be valid, a good basis for further investigations into the processes of Haversian system organization and the forces which affect them during development of the individual will be provided. The extreme differences in form between the young and adult gorilla also give good material for studying the possible relationships of growth processes, mechanical stresses and Haversian system organization to each other, in attacking anthropological problems of form and function in the head region.

#### SUMMARY

Comparisons of split-line features of several areas of the skulls of an adult male gorilla and a juvenile of the same species are reported. The patterns are closely similar in the mandibular and maxillary regions, except at the mandibular notch. The split-lines of the young gorilla skull appear to be in transition from an earlier condition toward that of the adult in the supraorbital, lateral orbital and zygomatic regions. The area of origin of the temporal muscle shows a clear pattern corresponding to the direction of action of the fibers of the muscle, but much of this arrangement is not present in the adult specimen.

The differences indicate that considerable reorganization takes place in Haversian system patterns of the skull of the gorilla during growth. More specimens of all ages are required to determine the processes of rearrangement that take place. The extreme differences in both gross form and split-line orientation between juvenile and adult gorilla skulls make this animal a promising subject for investigation of relationships of form, function and bone organization during development.

## LITERATURE CITED

- AHRENS, H. J. 1936 Die Entwicklung der Spaltlinienarchitektur des knöchernen menschlichen Schädels. *Morphol. Jahrb.*, 77: 357-371.
- BENNINGHOFF, A. 1925 Spaltlinien am Knochen, eine Methode zur Ermittlung der Architektur platter Knochen. *Anat. Anz. (Ergänz. heft)*, 60: 189-206.
- HENCKEL, K. O. 1931 Vergleichend-anatomische Untersuchungen über die Struktur der Knochenkompakta nach der Spaltlinien-methode. *Morphol. Jahrb.*, 66: 22-45.
- SEIPEL, C. M. 1948 Trajectories of the jaws. *Acta Odontol. Scand.*, 8: 81-191.
- TAPPEN, N. C. 1953 A functional analysis of the facial skeleton with split-line technique. *Am. J. Phys. Anthropol.*, n.s. 11: 503-532.
- 1954 A comparative functional analysis of primate skulls by the split-line technique. *Hum. Biol.*, 26: 220-238.





# A COMPARATIVE STUDY OF THE PRIMATE FEMUR BY MEANS OF THE STRESSCOAT AND THE SPLIT-LINE TECHNIQUES<sup>1,2</sup>

F. GAYNOR EVANS

*Department of Anatomy, Wayne State University,  
College of Medicine*

AND

CHARLES W. GOFF

*Department of Orthopedic Surgery, Yale University,  
School of Medicine*

THIRTY-ONE FIGURES

## INTRODUCTION

The mechanical significance of bone architecture has been of interest to anthropologists, anatomists, and orthopedic surgeons for some time. Galileo (1638) is credited with the first recorded comments on the mechanical significance of bone form but the first real attempt at a mechanical interpretation of the arrangement of bony trabeculae was made by Ward in 1838. In 1857 Wyman interpreted the trabecular arrangement in the femur, talus, calcaneum, and vertebrae as "studs" and "braces" or compression and tension resisting bars, respectively. A year later Humphry (1858) noted that the lines of trabeculae seen in frontal sections of the femur cross each other at right angles and are perpendicular to the articular surface of the head. The significance of this observation was not appreciated until the engineer and mathematician, Culmann, noted in some sections of bones exhibited by Hermann von Meyer (1867) at a scientific meeting in

<sup>1</sup> This research was supported (in part) by U. S. Public Health Grant A-377(C6).

<sup>2</sup> Read before the American Association of Physical Anthropologists, Chicago, Illinois, April, 1956.

Zurich, that the trabecular arrangement in a frontal section of a femur is similar to the trajectories, or lines of maximum internal stress, in a similarly formed and loaded engineering structure. Culmann's trajectorial diagram of a Fairbairn crane was compared with the trabecular arrangement in the proximal end of the femur, when viewed in the frontal plane, and served as the basis for the Trajectorial Theory of bone architecture. This theory received its highest expression in Wolff's classic monograph on "The Laws of Bone Transformation" (1892).

The Trajectorial Theory of bone architecture has been severely criticized by many later investigators and is not as uncritically accepted as it formerly was. The more important of these criticisms as well as other studies on stress and strain in bones have been reviewed and discussed by Evans ('57).

All the preceding work was based on studies of trabecular arrangement in sections of bone or mathematical analysis of sections of bone under assumed conditions of loading. More recently the mechanical significance of bone form and architecture has been studied in intact bones by means of the split-line technique and strain sensitive lacquers. The split-line technique was developed by Benninghoff ('25) and has recently been employed by Seipel ('48), Tappen ('53, '54) and Mednick ('55). The split-line patterns are believed to indicate the orientation of the Haversian systems or osteones which is presumably determined by the mechanical forces (stresses) to which the bone is subjected in the living body.

The strain sensitive lacquers used in studying bone form are colophonium and stresscoat. Colophonium has been used by Küntscher ('34, '35) and Pauwels ('50), while stresscoat has been employed in an extensive series of studies on the skull, femur and pelvis (Evans, '55). The strain sensitive lacquers show the distribution of tensile and compressive strain in a bone under various types of loading and provide an excellent method for analyzing the mechanical behavior of intact bones under controlled experimental conditions. In

contrast to all other methods stresscoat has been used on intact bones in living animals (Gurdjian and Lissner, '45). Consequently, it is known for certain that the mechanical behavior of dry bones, as indicated by the stresscoat pattern, is similar to that of living bones under corresponding conditions of loading. This is not true of the split-line technique or any other method used in studying the mechanical significance of bone form and architecture.

The present comparative study of stresscoat and split-line patterns in the same bone was undertaken in an attempt to clear up a misunderstanding which has arisen in the interpretation of the mechanical significance of the respective types of patterns. The stresscoat tests were made by Evans, after which Goff made split-line patterns on the same bones.

#### MATERIALS AND METHODS

The bones in this study were obtained from the Peabody Museum, Yale University, through the courtesy of Professor J. T. Gregory, Curator of Vertebrate Paleontology, and consisted of one femur from each of the following primate genera: *Homo*, *Gorilla*, *Pan*, *Pongo*, *Papio*, and *Ateles*. One femur of *Euarctus* was also studied. Stresscoat and split-line patterns were made for each bone. The stresscoat tests were made in materials testing machines calibrated to an accuracy of  $\pm 1\%$ .

The principle upon which the stresscoat technique is based has been discussed by Evans and Lissner ('48) but this is the first time that it has been used to show areas of tensile and compressive strain simultaneously in a single bone. A load was slowly applied to the head of a vertically oriented stresscoated femur until a pattern appeared on the superior aspect of the neck and the latero-anterior aspect of the shaft. The bone was left under load for 15 to 30 minutes so that the stress coat lacquer had time to flow. The load was then slowly removed during which a second pattern appeared on the

inferior aspect of the neck and the medial aspect of the shaft. Both patterns were sprayed with statiflux powder to make them more easily seen and some of the cracks were traced with ink so they would show in a photograph. Generally black ink was used for the cracks constituting the pattern showing the distribution of tensile strain and white ink for those forming the compressive strain pattern. Statiflux powder has been previously used by Evans and Lissner ('55).

The split-line patterns on the same bones were made as follows: Each femur was prepared for split-line demonstrations by soaking it in a 10% hydrochloric acid solution until the outer surfaces were softened by decalcification. Usually 30 to 60 minutes in the weak acid bath permitted a stout hypodermic needle, mounted in a wooden handle, to penetrate the bone cortex to a depth of 1 mm. After wiping away the excess solution the needle was pushed into the softened bone and drawn forcibly along the surface. Split-lines of about 3 cm were obtained at a stroke. These were then stained by flowing India ink into them and wiping away the excess. The process was repeated, moving the needle to the left or right of the split obtained. In this way, from the dense zona compacta of the head, down and over the neck and toward a trochanter or down the shaft, splits were made and stained. Tappen checked this method and made helpful suggestions.

The split-lines at no time crossed each other. At the zona compacta of the head and at each trochanter, as well as along the intertrochanteric line, only points or dots were produced.

Benninghoff ('25), Seipel ('48), and Mednick ('55) were content with short broken splits. Pauwels ('50) and Tappen ('53, '54) preferred continuous splits. Their technique was superior. In this way the decalcified bones were divided into Haversian systems as far as their external surfaces were concerned. Stresscoat markings were still visible, although the acid solution had softened the material so that remarking was occasionally necessary.



## RESULTS

*Stresscoat tests*

As would be expected because of their similarity in shape and in loading, the stresscoat patterns obtained in the tests were about the same in all the bones (figs. 1-17). In each bone the superior aspect of the neck and the lateral aspect of the shaft were the regions of the bone subjected to tensile strain during loading. In extensive patterns or in bones with considerable anterior bowing the tensile strain pattern spread from the lateral aspect onto the distal third of the anterior aspect of the shaft.

In all bones the inferior aspect of the neck and the medial aspect of the shaft were the areas of the bone undergoing compressive strain during loading. In extensive patterns the posterior aspect of the distal third of the shaft was also involved.

The tensile and compressive strain patterns were generally well defined and not interrupted by areas with no cracks. The most marked exception to this condition was the human femur (figs. 1 and 2) in which a maximum load of 240 lbs. produced discontinuous tensile and compressive strain patterns. This condition is probably related to the slenderness of the bone and the rather pronounced anterior bowing of the shaft.

None of the bones were fractured during the tests. Consequently, the maximum load recorded for each bone is considerably below that which the bone could successfully support without breaking. The size of the bone, the thickness and degree of anterior bowing of the shaft, the torsion angle of the head, the inclination angle and the angle which the long axes of the neck and the shaft make with each other are anatomical factors influencing the extent of the various strain patterns obtained and the load necessary to produce them. Other factors are the age and state of health of the animal from whom the bone was taken, as well as the moisture content of the bone when tested.

The stresscoat patterns obtained in the bones indicated that the tensile and compressive strain responsible for the patterns was in the direction of the long axis of the neck and the shaft. In previous studies of the mechanical behavior of the human femur under static vertical loading Evans and Lissner ('48) found that the first cracks of the tensile strain pattern appeared on the superior aspect of the neck close to the head and on the lateral aspect of the shaft a few inches distal to the insertion of the gluteus minimus muscle. With increasing load other cracks appeared as the pattern extended along the neck and the shaft. The place where the first cracks of the compressive strain pattern appeared was not observed.

The site where the first cracks appear indicates the area of highest strain and, in the case of the tensile strain pattern, the place where failure or fracture will occur if a sufficiently large load is applied. This has been repeatedly confirmed in experimentally produced fractures of the skull (Gurdjian and Lissner, '45; Gurdjian, Lissner and Webster, '47; Gurdjian, Webster and Lissner, '49, '50a and b), of the femur (Evans and Lissner, '48; Evans, Lissner and Pedersen, '48; Pedersen, Evans and Lissner, '49) and of the pelvis (Evans and Lissner, '55).

In bones with extensive stresscoat patterns extending the length of the shaft the cracks at the proximal and distal ends of the bones (figs. 3-8; 12-14) were curved with the convexity of the curve directed towards the ends of the bones. The stresscoat cracks represent part of tensile and compressive stress trajectories and if projected would cross each other as indicated in (figs. 18-19). In this figure the tensile trajectories are indicated in black broken lines and the compressive trajectories in white broken lines. If the magnitude of the stress were actually computed at various points and these trajectories shown in a trajectorial diagram they would have to cross one another at a 90° angle. However, a bone is not a plane surface like a trajectorial diagram and in extending the lines from the stresscoat cracks it was difficult to draw them on the curved surface of the bone so that they would

cross exactly at a right angle. The tensile and compressive trajectories on the neck of the bone are also indicated.

### *Split-line patterns*

In most instances the split-lines (figs. 20-25) were nearly parallel, no matter how close together they were made. As described, they at no time crossed one another. These lines assumed a longitudinally striate pattern extending from the margins of the zona compacta of the head, radiating out over the globular structure and down onto the neck. They coursed their way toward the trochanters and the intertrochanteric line and crest. At the latter two, they described curving lines, joining with the directional prominence of each.

A similar pattern with specific variations occurred in the femurs of all species studied, although the human femur, as shown by Pauwels (fig. 29) had a less prominent ridge at the intertrochanteric line. The needle could not be drawn in any direction over the trochanters, the ridges or zona compacta of the femoral head. Even if decalcified to a greater extent these very dense regions demonstrated a pattern expressed as dots. This seemed to indicate the end of an Haversian column or osteone. Blood vessels probably traversed these open ends where tendons or capsular structures attached.

The spider monkey and the orangutan had a small zona compacta and prominent trochanters. The chimpanzee, gorilla and man had the largest zona compacta. This probably represents a greater weight bearing surface as a functioning correlation. The area surrounding the fovea centralis appeared as a pattern of dots surrounded by curving split-lines. In the baboon the head of the femur presented a pattern of dots that was relatively the largest with the fovea centralis near its center.

### DISCUSSION

To those unfamiliar with its use the significance of patterns obtained with the stress coat method may not be clear. "Stress-

coat'' is simply the trade name for the brittle resinous lacquer used in the method. It is an unfortunate choice for a name because it conveys an erroneous impression. The patterns obtained by use of stresscoat are *strain*, not stress, patterns and only arise from *tensile strain* in the material upon which the lacquer has been sprayed.

Strain is a change in the linear dimensions of a body as the result of the application of a force. Stress is the intermolecular resistance within the material of a body to the deforming action of a force. A force is a push or a pull. Strain can be seen if it is large enough, e.g., the stretching of a rubber band, but stress never can be seen and is always a derived quantity. The value for stress is computed in terms of load per unit area ( $\text{kg}/\text{cm}^2$  or  $\text{lbs. in.}^2$ ) but there are no standard units of measurement for strain which can be expressed in inches/inch or percentage change in the dimensions of the body as the result of the application of a force.

During the stresscoat tests the femur was subjected to both tensile and compressive strain and stress. *Tensile* strain occurred in the superior aspect of the neck and the latero-anterior aspect of the shaft, as the bone was bent by the slowly increasing load, and was responsible for the appearance of the stresscoat cracks in those regions. These cracks constituted the first pattern which indicated the location and extent of the *tensile* strain produced by the test load.

The load applied to the bone also produced compressive strain but its location and extent were not immediately visible. Leaving the femur under load for several minutes gave the lacquer an opportunity to flow so that when the load was gradually removed and the bone slowly returned to its original dimensions cracks appeared on the inferior aspect of the neck and the medial aspect of the shaft. These cracks, constituting the second stresscoat pattern, actually arose from tensile strain produced by the stretching of the bone as it returned to its pretest dimensions. However, this second pattern lies in the regions of the bone subjected to *compressive*



strain during loading and thus indicates the location and extent of *compressive* strain in the bone when loaded.

Stresscoat patterns reveal the location and extent of tensile strain produced in a body by different types of loading. The place where the cracks first appear is the site of highest tensile strain where failure can be predicted to occur if a large enough load is applied. The method is widely used in industry for studying strain distribution with reference to points of weakness and failure in engineering structures, machine parts, etc.

The stresscoat method is excellent for studying the mechanical behavior of a body under various types of loading but is of relatively little direct use in analysing the composition of the material composing the body. Thus, a piece of wood, bone or metal of similar shape and dimensions would, if similarly loaded, have the same type of stresscoat pattern. The extent of the pattern under a given load would, of course, vary with the material composing the body, a greater load being required to produce a stresscoat pattern of a given extent in a steel bar than in a wooden or bony one of the same shape and dimensions. From examination of a stresscoat pattern one can deduce the type of loading responsible for the pattern but little regarding the finer structure of the body on which the pattern was obtained.

Split-line patterns are said to indicate the orientation of the Haversian systems or osteones of a bone but the mechanical significance of this orientation has not yet been proved. Benninghoff ('27) reported that the split-line patterns of rachitic femurs are different from those of normal bones, while Seipel ('48) found differences between split-line patterns of normal mandibles and imperfectly set fractured ones. Dowgjallo ('32) also studied the mandible with the split-line method and reported that the structure of the mandible changed with alterations of function associated with the loss of teeth. However, Benninghoff, cited by Murray ('36), stated that some of the patterns found by Dowgjallo were

within the normal range of variation of jaws with complete functioning dentition.

In some recent studies with the split-line method the split-line patterns were explained in terms of the mechanical stresses and strains to which the bone had been supposedly subjected in the living animal. In the case of the facial skeleton (Tappen, '53, '54) muscle action in chewing was considered to be responsible for the stresses and strains in the bones. However, the arguments advanced in support of this thesis are largely theoretical without experimental confirmation.

These investigators, in presenting the results of their studies, frequently refer to the split-lines as "lines of stress" or imply that they represent stress trajectories. However, as mentioned previously, stress cannot be seen and, except in certain plastics when viewed under polarized light, neither can a stress trajectory. A stress trajectory is defined in mechanics as the curve along which the principal stresses at any point will fall. Therefore, the magnitude of the principal stresses must be computed before a stress trajectory can be determined or drawn. This has never been done for any bones studied by the split-line method.

Split-lines most probably should be ruled out as representing stress trajectories for another reason. Stresses occur in pairs, tensile and compressive, and the respective tensile and compressive stress trajectories always cross one another at a  $90^\circ$  angle. Examination of figures 20-25, as well as those given by Benninghoff, Seipel, Tappen and Mednick, reveals that the split-lines rarely, if ever, cross one another.

Another factor to be considered is that engineers only draw trajectorial diagrams when analysing bodies which are solid and composed of homogeneous material. A bone is not a solid body and is of heterogeneous composition, the ordinary constituents being osteocytes, collagen fibers, cement substance, the inorganic matrix, and such adventitious elements as Sharpey's fibers. Thus, a bone is not the kind of a body for

which engineers draw trajectorial diagrams for stress analysis.

Seipel (loc. cit.), who used the split-line method in a classic study of the jaws and facial skeleton, emphasized that "*extreme caution has to be exerted in the application of mechanical laws.*" He also stated that "the tracing of a single abstracted force or external stimulus to a definite structural arrangement is seldom to be made." Seipel was careful to point out that "*the coloring lines are by no means trajectories (meaning structural lines of stress), only indicators of the main flow of lamellar and fibrous organization in the bone.*" Seipel also made histological preparations of his specimens so that he could study the relations between the split-lines and the microscopic conditions of the bone, but this has rarely been done by other modern users of the method. In discussing bone adaptation Seipel stated that biological factors as well as mechanical stimulation should be considered, and that "*changes in the form, function, elementary composition, or nutritional and vascular conditions of bone, produce changes in its interior architecture and trajectorial qualities.*" Unfortunately, many people who work with bone forget that living bone is a very active and plastic tissue quite different from the way it appears in a prepared skeleton.

There is ample experimental and clinical evidence that the orientation of the trabeculae of a bone is strongly influenced by the mechanical stresses to which the bone is subjected, *but this is not true for the orientation of the osteones.* Osteones undoubtedly have some functional significance but this may be a question of the amount of material they represent rather than their orientation. Thus, other things being equal, a body composed of the most material is the strongest. In addition to the actual amount of material present, the way in which it is distributed is also an important factor influencing the strength and mechanical behavior of a body. For example, a tubular structure, in proportion to the amount of material present, is stronger in resisting bending action than is a solid rod. This principle is beautifully seen in the structure of a

long bone which has to resist considerable bending action during body movements.

The idea that the orientation of osteones is determined or markedly affected by mechanical stresses and strains is very appealing but we believe there is strong evidence against it. As pointed out by Amprino and Bairati ('36) the squamous part of the occipital bone is rich in osteones yet it is not subjected to any great mechanical stresses. The same is true of the other bones of the skull vault, and Benninghoff ('25) was unable to obtain any split-line pattern in this region of the skull. This seems strange if, as some users believe, the split-lines indicate the strain orientation of osteones. It is interesting to note that Ilberg ('35) obtained well-defined split-line patterns in human septal and nasal cartilages (figs. 26-28), although cartilage has no osteones! It is also difficult to imagine any great mechanical stresses acting on the nasal cartilages and Ilberg was unable to give a satisfactory explanation of the split-line patterns.

Amprino and Bairati (loc. cit.), on the basis of histological studies of specimens from the middle segment of 100 femurs of individuals varying from a fetus 8 months of age to a man 94 years of age, concluded that osteones should be considered in relation to growth processes and vascularization, i.e., nutrition, of bone. They also found greater structural differences in the femur than between different bones of the same individual. This is interesting because the femurs would be subjected to similar mechanical stresses whereas, compared with the femur, there would be considerable variation in the mechanical stresses acting on other bones.

If mechanical stresses induced by function are important in determining the histological structure of bone, one should find marked differences between the histology of normal bones and that of non-functional bones. However, F. Vigliani ('52) found that immobilization of a bone has practically no effect on its histological and ultrastructure. In his experiments on dogs one front limb was immobilized by fixation to the thoracic wall or by fixation accompanied by complete denervation.



The operations were done at the beginning of a growth period. In each dog the opposite normal functioning foreleg was the control.

At the termination of the experiments the animals were killed and the long bones from the immobilized and the functional leg were studied histologically. It was found that the limiting system, the osteones or Haversian systems, was formed and renewed in the inactive bone in an entirely normal manner. Furthermore, structures of the third order (collagen fibers) were identical with those in bones which had developed in full mechanical activity. Regardless of the external influences the bony tissue has interlacing or parallel fibers progressively replaced by lamellar bone. This process occurred simultaneously in the bones from the immobilized and the functional limbs. Immobilizing the bone so as to remove it from mechanical stresses had a quantitative, not a qualitative, effect on the bone, the bones from the non-functional limb being smaller than those from the normal limb. Amprino ('51) reported the same results from histological study of human bones from limbs which had been paralyzed for about 10 years, the structural transformations in the bones from the paralyzed limbs being coincident with those in bones from normal individuals of the same age.

If mechanical stresses are responsible for the orientation of osteones, as revealed by the split-line method, this should be especially pronounced in areas of muscle attachment. This would be particularly true for tendon attachments because the tensile stress arising from muscle contraction is concentrated at a localized area. Examination of figures 20, 21 and 25 shows that the split-line pattern on the greater and lesser trochanter, the areas of insertion of the gluteus medius and minimus and of the iliopsoas muscles, respectively, is poorly developed and limited to dots rather than well-defined lines, as in other regions of the bone.

Stilwell and Gray ('54) recently made a histological study of the periosteum and adjacent compact bone underlying 128 tendons from 15 different areas of tendinous contact. Their

material was obtained from 18 human cadavers varying from 43 to 85 years of age. Although some variation was found in periosteum and the thickness and cellularity of the fibrocartilage covering the bone under the tendons, the adjacent compacta appeared to be unmodified by the tendinous contact. Except for deficiencies for the passage of blood vessels from the spongiosa to the periosteum, the compacta in the area of tendon contact was structurally similar to and no thicker than compacta elsewhere.

From x-ray diffraction and x-ray absorption studies Engstrom and Amprino ('50) were unable to find any differences in the distribution and concentration of minerals between normally functioning and mechanically inactive bones of dogs. From these and many similar studies Amprino (*loc. cit.*) concluded that "it appears certain that the static and dynamic mechanical stimulations to which bones are subjected do not have a direct influence on the arrangement and structure of the osteones." He also points out that in the same section of any long bone, which is obviously acted upon by equivalent mechanical stresses, structures of the second (osteones and fundamental lamellar systems) and third (collagen fibers) orders vary vastly from one another with age. In young individuals the osteones are large and irregular but in adult and old individuals they are much smaller and regularly disposed. More recently Knese, Voges and Ritschl ('54), in polarized light studies of cross sections of extremity bones from a man 43 years of age, found that the osteone is not a constant cylinder, the osteone lamella not a regular and equal tube and the tangential lamella not a plain leaf. The peripheral half of the sections generally had the smaller osteones while the central half had the larger ones. The smaller osteones frequently lacked the lamellar formation seen in the larger ones.

The above findings do not mean that mechanical forces or stresses have no effect on the histology and ultrastructure of bone but only that they do not have a *dominate* influence. Thus, Tischendorf ('51) observed during bending, very minute

(considerably less than  $1\mu$ ) interlamellar shifts in fresh specimens of human compacta bone. Amprino (loc. cit.) believes that external mechanical influences have a *complementary role in normal bone development* and regulate, at least in part, the quantity of bony tissue and, perhaps, the disposition of cavities excavated in the ground substance during modification. Amprino and Bairati (loc. cit.) explained the structural differences they found in specimens of compacta from individuals of various ages on the basis of more or less rapid growth phenomena, especially with modification of the vessels of the compacta in different ages.

The influence of the blood supply on the histological structure of compact bone has been discussed by Ham ('52), who emphasizes that "the size of a Haversian system, like the thickness of a trabecula in cancellous bone, is limited by the necessity of having all the bone cells which it contains no farther than about one-tenth of a millimeter from a capillary." He also points out that practically all the Haversian vessels were originally periosteal vessels which became buried deeper and deeper in the cortex as the bone grew in diameter. Since the vessels in the Haversian canals run more or less longitudinally in the shaft of a bone the Haversian systems do likewise. Tischendorf (loc. cit.) also states that "the Haversian systems of the compacta do not run strictly parallel to the longitudinal axis of the long bones but rather follow the course of blood vessels." In discussing the structure of osteones and lamella Knese, Voges and Ritschl (op. cit.) concluded that they represent special depositions of collagen fibers whose circular arrangement is dependent on the vascular tree. The circular windings represent a system accompanying the vascular tree in a more or less continuous connection.

The results, reviewed above, obtained by different investigators using various methods indicate that the histological and ultrastructure of compact bone is not dependent upon external mechanical stresses. Therefore, the split-line patterns probably should not be interpreted in terms of mechanically induced stresses. Pauwels ('50) points out that a long

bone, under normal loading, is subjected to a combination of bending and shearing forces. Because of the superimposed shearing stresses the functional tensile trajectories, i.e., trajectories arising from opposite aspects of the bone, must cross one another at right angles. However, the trajectories of the force field for growth are longitudinally arranged, parallel with the long axis of the bone and do not cross. The functional trajectories, according to Pauwels, are evident in the main trabecular lines of the spongiosa. The growth trajectories are embodied in the osteones whose course can be represented by the split-line method. Comparison of the split-line pattern in a femur (fig. 29) with the functional stress trajectories produced in the same bone by the colophonium method (figs. 30, 31) shows that the two line systems are fundamentally different and that "the osteones are not adjusted as stress trajectories for the requirements of the bone."

Since split-line patterns are considered to indicate the orientation of Haversian systems or osteones a brief discussion of the structure of an osteone is in order. Pritchard ('56) points out that the term "osteone" is preferable to "Haversian system" because the latter is too strongly associated with a two-dimensional appearance in cross sections of bone, whereas an osteone is actually three-dimensional. The concept of an osteone as a series of separate concentric cylinders is erroneous because, according to Pritchard, an osteone is more analogous to a spool of thread. Furthermore, if osteones are followed along the axis of a bone they are "seen to branch and anastomose with neighboring osteones as the vessels within the central canals branch and anastomose." Pritchard also emphasized *that bone is not composed of structural units, or building blocks, at any organization level above the sub-microscopic.*

An osteone is not a static feature and a section of any bone will reveal osteones in various stages of formation and resorption. As Pritchard states, the writing or speaking of bone as if it were composed of separate structural units or blocks is "dangerous when it leads to a belief in the real



existence of such units and when elaborate mechanical analyses are founded on such beliefs." Many studies of the histology and ultrastructure of bone lead to the conclusion that bone is a continuum and that its apparent unitary features are the result of its conformity to external factors such as blood vessel patterns, and not to growth from the accumulation of similar structural units (Pritchard, '56).

#### SUMMARY AND CONCLUSIONS

1. Stresscoat and other strain sensitive lacquers show the location and extent of strain produced in a bone by different types of loading.

2. Strain sensitive lacquers are useful in studying the mechanical behavior of an intact bone under various conditions of loading but provide little direct information on the histology and ultrastructure of the bone.

3. The patterns obtained by use of the stresscoat method are *strain, not stress, patterns* and only arise from *tensile strain* in the underlying material.

4. Strain in a body can be seen if it is sufficiently large but stress is always a derived quantity.

5. Stress trajectories or "lines of stress" cannot be seen in a bone and a bone is not the type of body for which trajectorial diagrams can be properly drawn.

6. The split-line method is useful as an indicator of structural arrangement but is of little aid in analyzing the mechanical significance of bone architecture.

7. Split-lines do not fulfill the requirements of stress trajectories and should not be interpreted as such. It is suggested that they might be considered directional growth indicators of the spiral like osteones. As such they have functional meaning and assist in the comprehensive analysis of bone composition.

8. Studies by many investigators using different techniques indicate that the orientation of osteones is not primarily determined by mechanical stresses.



## LITERATURE CITED

- AMPRINO, R. 1951 Relations entre la structure et la physiologie de l'os. *Ann. Soc. Roy. Sci. des Med. et Nat. (Bruxelles) Fasc.*, 6: 209-225.
- AMPRINO, R., AND A. BAIRATI 1936 Contributo allo studio del valore funzionale della struttura della sostanza delle ossa. *Shir. degli Organi di Movimento*, 20: 527-541.
- BENNINGHOFF, A. 1925 Spaltlinien am Knochen, ein Method zur Ermittlungen der Architektur platte Knochen. *Verh. Anat. Gesel. Suppl., Anat. Anz.*, 60: 189-206.
- 1927 Ueber die Anpassung der Knochenkompakta an geänderte Beanspruchungen. *Anat. Anz.*, 63: 289-299.
- DOWGJALLO, N. D. 1932 Die Struktur der Compacta des Unterkiefers bei normalem und reduzierten Alveolarfortsatz. *Zeitschr. Anat. Ent.-gesch.*, 97: 55-67 (*Ztschr. f. gesamte Anat., Abt. 1*).
- ENGSTRÖM, A., AND R. AMPRINO 1950 X-ray diffraction and x-ray absorption studies of immobilized bone. *Experientia*, VI: 267-275.
- EVANS, F. GAYNOR 1953 Methods of studying the mechanical significance of bone form. *Am. J. Phys. Anthropol.*, n.s. 11: 413-436.
- 1955 Studies in human biomechanics. *Ann. N. Y. Acad. Sci.*, 63: 586-615.
- 1957 Stress and Strain in Bones. Their Relation to Fractures and Osteogenesis. Charles C Thomas, Springfield, Ill.
- EVANS, F. GAYNOR, AND H. R. LISSNER 1948 "Stresscoat" deformation studies of the femur under static vertical loading. *Anat. Rec.*, 100: 159-190.
- 1955 Studies on pelvic deformations and fractures. *Anat. Rec.*, 121: 141-168.
- EVANS, F. GAYNOR, H. R. LISSNER AND H. E. PEDERSEN 1948 Deformation studies of the femur under dynamic vertical loading. *Anat. Rec.*, 101: 225-241.
- GALILEO, G. L. 1638 Discorsi e Dimostrazioni Matematiche. Tran. by H. Crew and S. deSalvio. Northwestern Univ. Press.
- GURDJIAN, E. S., AND H. R. LISSNER 1945 Deformation of the skull in head injury. *Surg. Gyn. Obst.*, 81: 679-687.
- GURDJIAN, E. S., AND H. R. LISSNER 1946 Deformation of the skull in head injury studied by the "stresscoat" technique, quantitative determinations. *Surg. Gyn. Obst.*, 83: 219-233.
- 1947 Deformations of the skull in head injury as studied by the "stresscoat" technic. *Am. J. Surg.*, 73: 269-281.
- GURDJIAN, E. S., J. E. WEBSTER AND H. R. LISSNER 1949 Studies on skull fracture with particular reference to engineering factors. *Am. J. Surg.*, 78: 736-742.
- 1950a The mechanism of skull fracture. *J. Neurosurg.*, 7: 106-114.
- 1950b The mechanism of skull fracture. *Radiology*, 54: 313-339.
- GURDJIAN, E. S., H. R. LISSNER AND J. E. WEBSTER 1947 The mechanism of production of linear skull fracture. Further studies of deformation of the skull by the "stresscoat" technique. *Surg. Gyn. Obst.*, 85: 195-210.

- HAM, A. W. 1952 Some histophysiological problems peculiar to calcified tissue. *J. Bone and Joint Surg.*, 34-A: 701-728.
- HUMPHRY, G. M. 1858 *A Treatise on the Human Skeleton*. Cambridge.
- ILBERG, A. 1935 Ueber die funktionelle Architektur der Naselknorpel und ihre knöchernen Umgelung beim Menschen. *Ztschr. f. Laryng. Rhin. Otol.*, 26: 239-257.
- KNESE, K.-H., D. VOGES AND I. RITSCHL 1954 Untersuchungen über die Osteon- und Lamellenformen im Extremitätenskelet des Erwachsenen. *Ztschr. f. Zellforsch.*, 40: 323-360.
- KÜNTSCHER, G. 1934 Die Darstellung der Kraftflusses im Knochen. *Zentralbl. f. Chir.*, 61: 2130-2136.
- 1935 Die Bedeutung der Darstellung des Kraftflusses im Knochen. *Archiv. f. Klin. Chir.*, 182: 489-551.
- MEDNICK, L. W. 1955 The evolution of the human ilium. *Am. J. Phys. Anthrop.*, n.s. 13: 203-216.
- MEYER, H. VON 1867 Die Architektur des Spongiosa. *Archiv. Anat. Physiol.*, 34: 615-628.
- MURRAY, P. D. F. 1936 *Bones*. 1-203, Cambridge Univ. Press.
- PAUWELS, F. 1950 Über die mechanische Bedeutung der größeren Kortikalisstruktur beim normal und pathologisch verbogenen Röhrenknochen. *Anat. Nachrichten*, 1: 53-67.
- PEDERSEN, H. E., F. GAYNOR EVANS AND H. R. LISSNER 1949 Deformation studies of the femur under various loadings and orientations. *Anat. Rec.*, 103: 159-186.
- PRITCHARD, J. J. 1956 General anatomy and histology of bone. Chap. 1, 1-26. (In *The Biochemistry and Physiology of Bone*, G. H. Bourne, Ed., 1-875, Academic Press, N. Y.)
- SEIPEL, C. M. 1948 Trajectories of the Jaws. 1-115, P. A. Norstedt and Söner, Stockholm. (Reprinted from *Acta Odont. Scand.*, 8: 81-191, 1948.)
- STILWELL, D. L., JR., AND D. J. GRAY 1954 The microscopic structure of periosteum in areas of tendinous contact. *Anat. Rec.*, 120: 663-677.
- TAPPEN, N. C. 1953 A functional analysis of the facial skeleton with split-line technique. *Am. J. Phys. Anthrop.*, n.s. 11: 503-532.
- 1954 A comparative functional analysis of primate skulls by the split-line technique. *Human Biol.*, 26: 220-238.
- TISCHENDORF, F. 1951 Das Verhalten der Haversschen Systeme bei Belastung. I. Mitteilung. Untersuchungen über das Knochengewebe. *Roux's Archiv. f. Entwicklgsmech.*, 145: 318-332.
- VIGLIANI, F. 1952 Accrescimento in lunghezza di ossa tubulari in arti sottratti sperimentalmente al carico meccanico. *Archive "Putti" di Chir. degli Organi di Movimento.*, 2: 207-221.
- WARD, F. O. 1838 *Outlines of Human Osteology*. London.
- WOLFF, J. 1892 *Das Gesetz der Transformation der Knochen*. Berlin.
- WYMAN, J. 1857 On cancellate structure of some of the bones of the human body. *Boston, J. Nat. Hist.*, 6: 125-140.

## PLATE 1

### EXPLANATION OF FIGURES

- 1-2 Human femur with stresscoat markings outlined in India ink. "A" indicates TENSILE and "B" COMPRESSIVE strain areas — femur loaded vertically with 240 lbs. maximum.
- 3-5 Gorilla femur with "A" indicating TENSILE strain areas, while "B" and "C" show COMPRESSIVE strain zones — femur loaded vertically with 800 lbs. maximum.

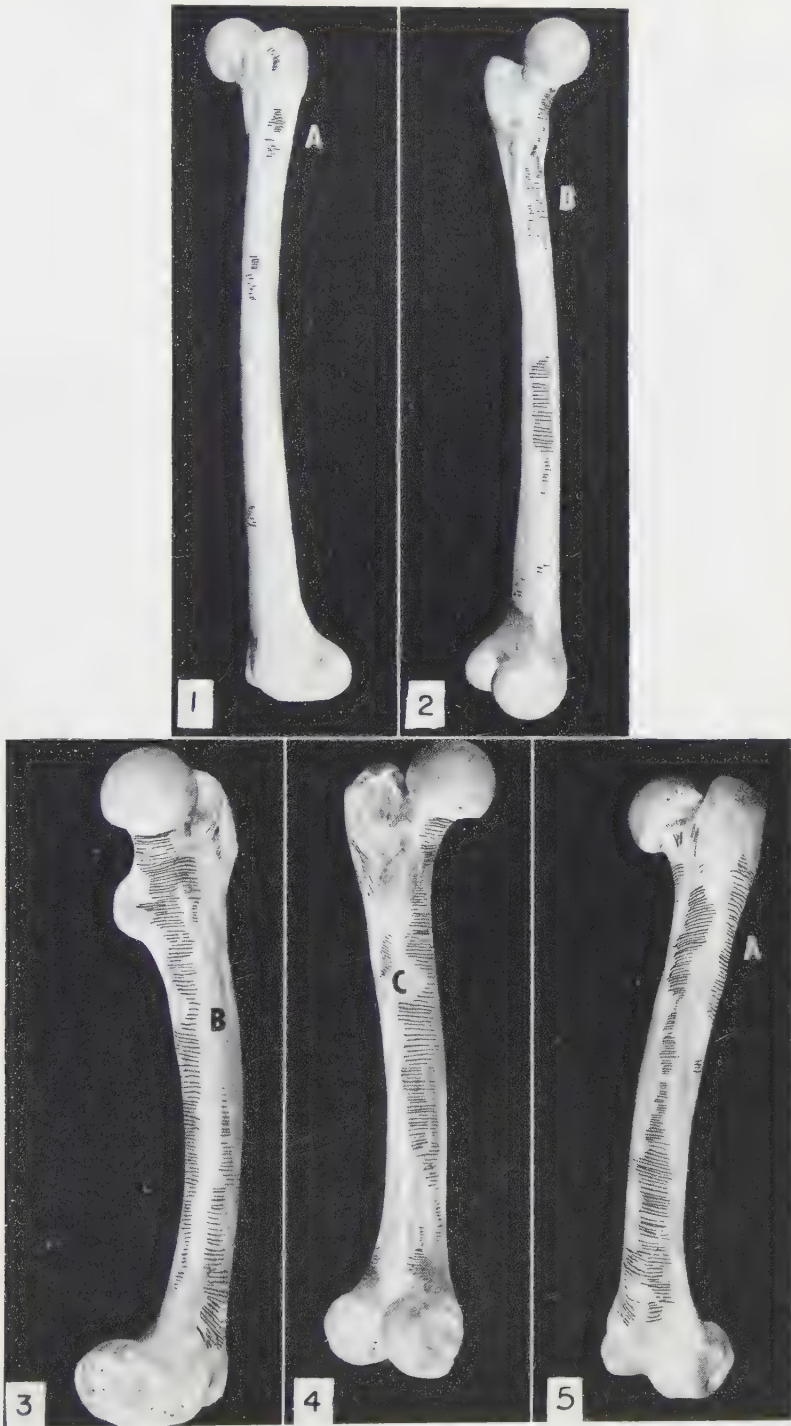


PLATE 2

EXPLANATION OF FIGURES

6-11 Chimpanzee femur loaded with 200 lbs. maximum — TENSILE strains marked in *black lines* and COMPRESSIVE strains by *white lines*.



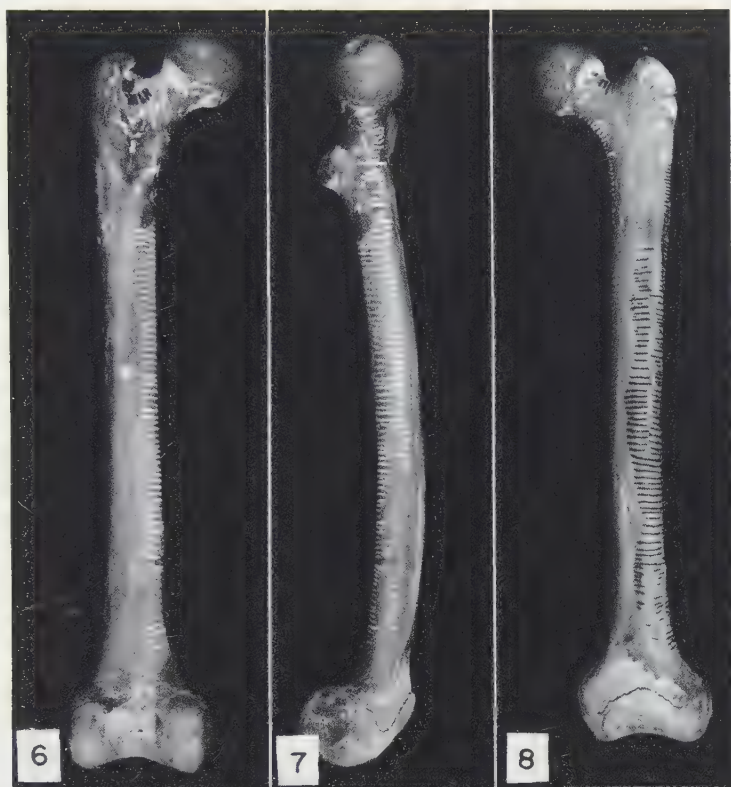
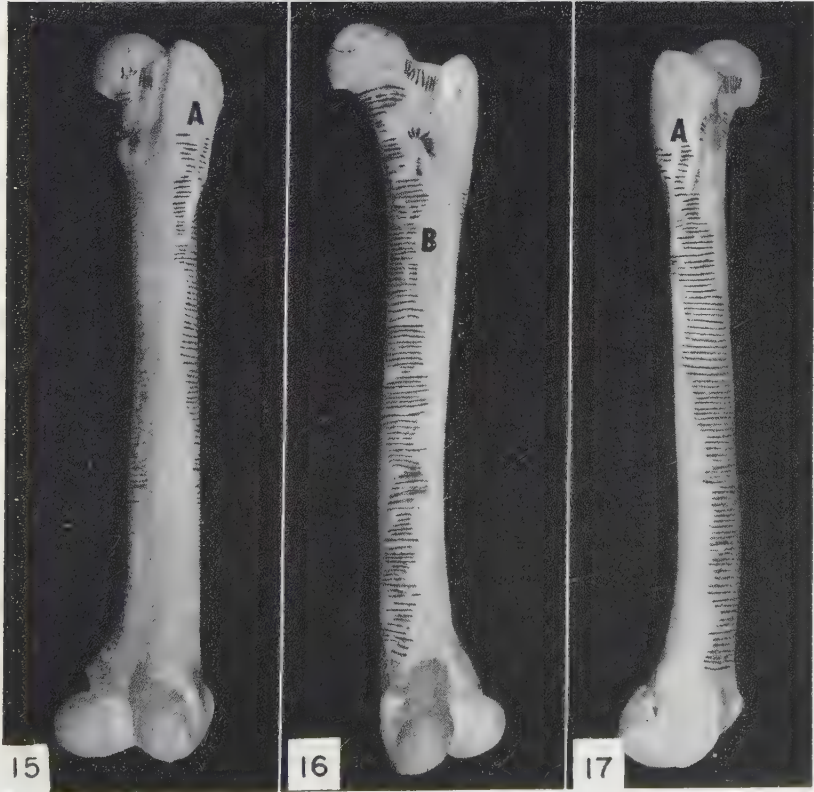
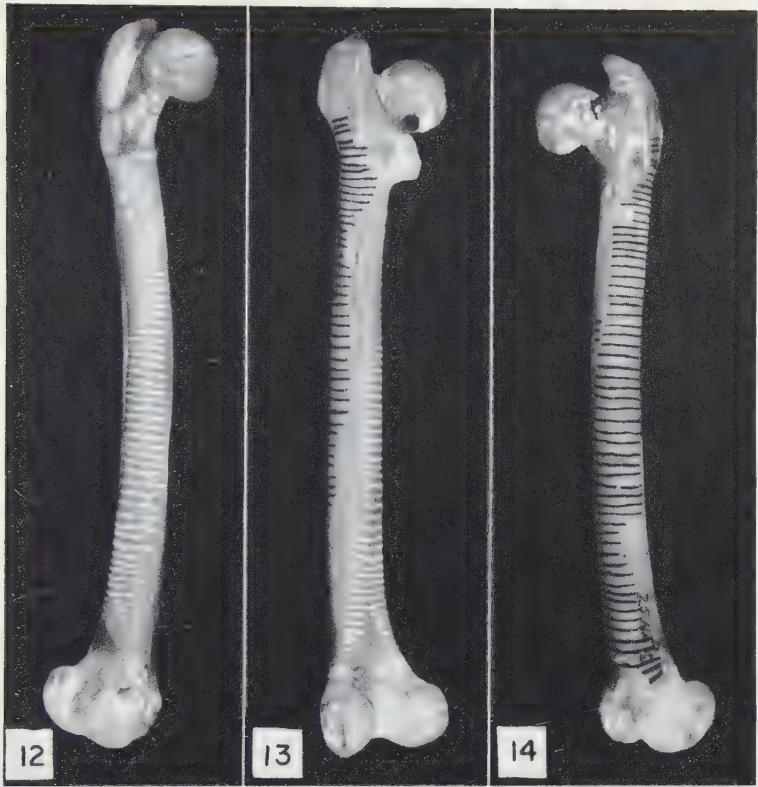


PLATE 3

EXPLANATION OF FIGURES

- 12-14 Baboon femur loaded with 125 lbs. maximum — TENSILE strains marked in *black lines* and COMPRESSIVE strains by *white lines*.
- 15-17 Black bear femur loaded with 730 lbs. maximum — TENSILE strains “A” and COMPRESSIVE strains “B.”



## PLATE 4

### EXPLANATION OF FIGURES

- 18-19 Chimpanzee femur loaded with 200 lbs. maximum — TENSILE trajectories drawn in *black broken lines* and COMPRESSIVE trajectories in *white broken lines*. See text for explanation.

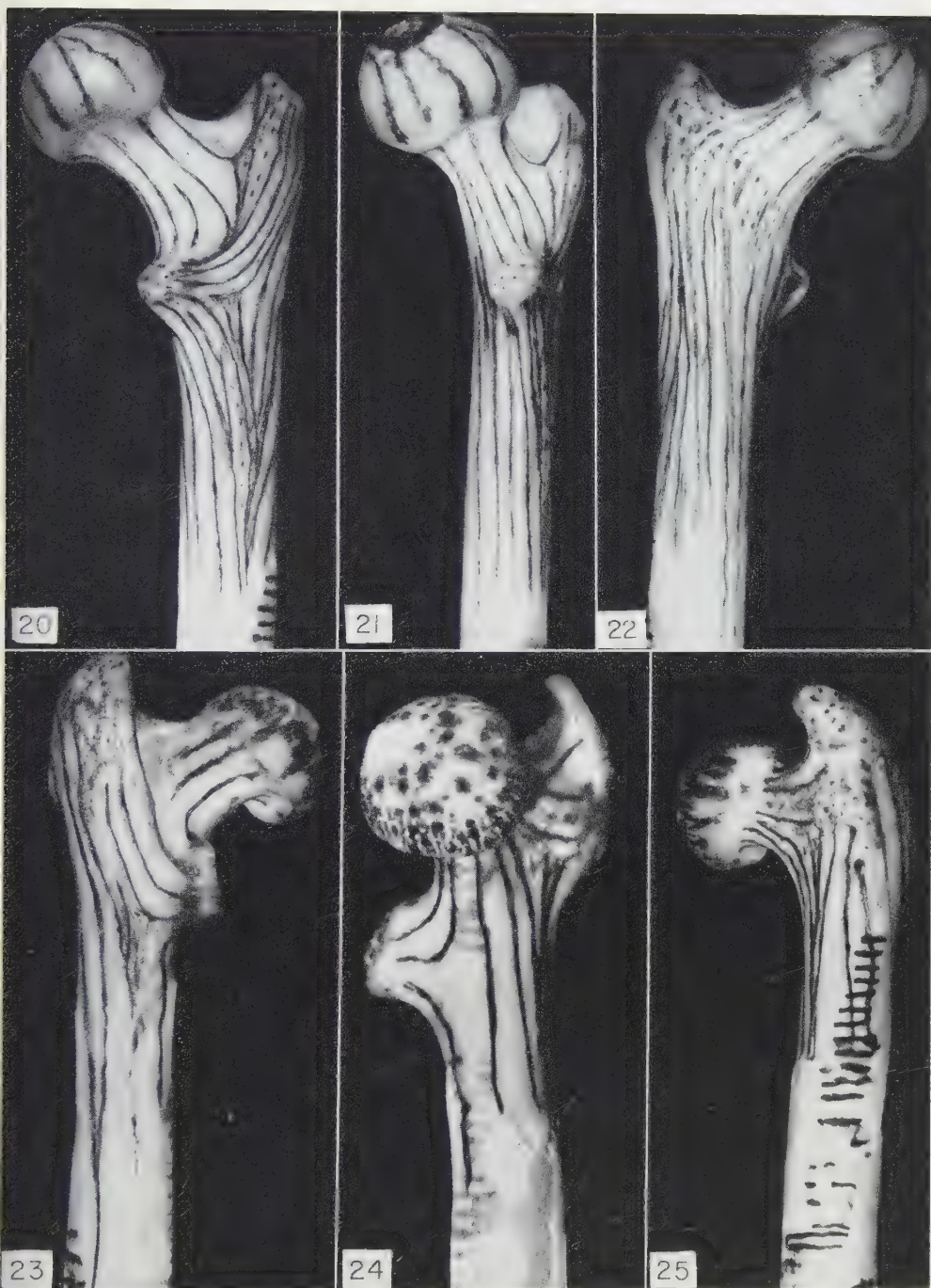




## PLATE 5

### EXPLANATION OF FIGURES

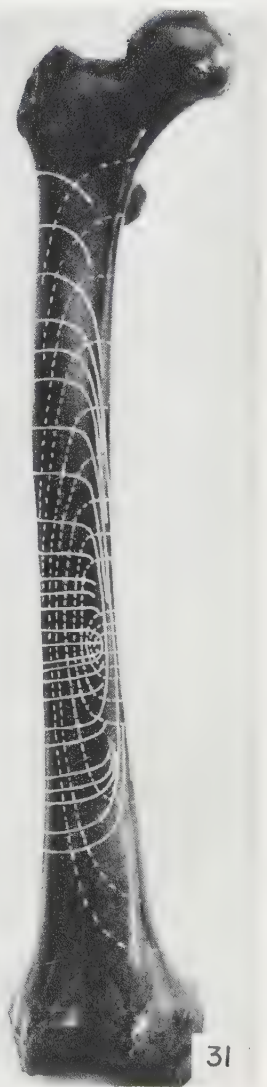
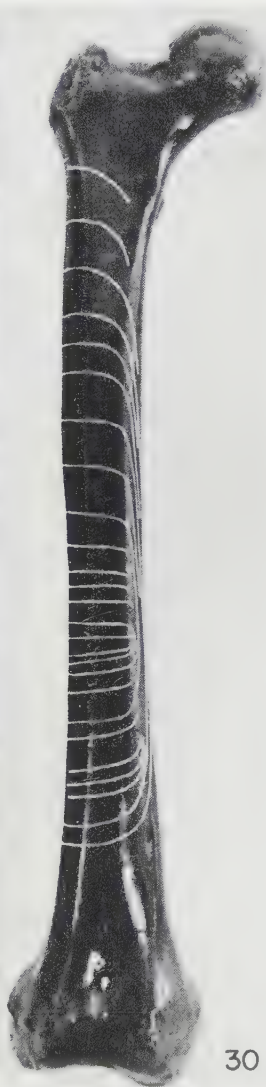
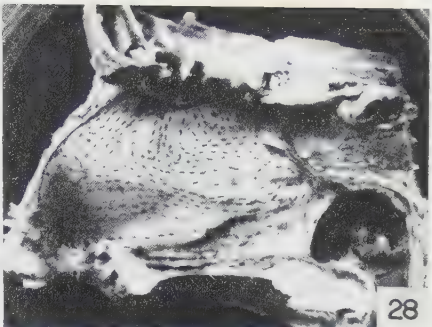
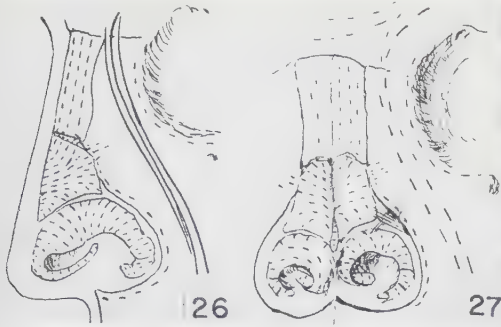
- 20-22 Orangutan femur showing split-line patterns produced after stresscoat studies had been made. Some of the latter markings are still present about the lower margins of illustrations. Note split Haversian systems, indicated by lines, and open end systems, indicated by dots, at trochanters, articular *zona compacta* and the linea aspera. See text for explanation.
- 23-25 Baboon femur showing split line patterns.



## PLATE 6

### EXPLANATION OF FIGURES

- 26-28 Human nasal cartilage split-line patterns, by Ilberg ('35).  
29 Human femur with split-line patterns, from Pauwels ('50).  
30-31 Same femur showing TENSILE and COMPRESSIVE trajectories using colophonium coating, from Pauwels ('50).







# PHYSICAL FEATURES, SICKLING AND SEROLOGY OF THE MALAGASY OF MADAGASCAR<sup>1</sup>

R. SINGER, O. E. BUDTZ-OLSEN,<sup>2</sup> P. BRAIN  
*Departments of Anatomy, Physiology, Pathology,*  
*University of Cape Town*

AND

J. SAUGRAIN  
*Hospital de Befelatanana, Tananarive*

SIX FIGURES

## INTRODUCTION

### 1. General

The island of Madagascar, 1000 miles long and 300 miles wide, lies between 12 and 26 degrees latitude. It is separated from the east coast of Africa by the 300-mile wide Mozambique Channel. A longitudinal chain of mountains down the central part forms the principal watershed and divides the island into two parts: a narrow eastern section which slopes abruptly, discharging numerous rivers through deep forest gorges into the sea; and a large western section whose major portion forms the central highlands 3000-5000 ft. high. The general appearance of these elevated highlands is monotonous, consisting of vast undulating hills in steppe-like tracts covered with long coarse grass and stunted herbage. The climate of this region is much healthier than that of the fever-stricken plains of the coastal regions which are hot and humid. In the extreme south-west rain is rare and the arid, sandy desert is scorched by sun and hot winds.

<sup>1</sup> A grant from the Wenner-Gren Foundation for Anthropological Research covers the cost of publishing this paper.

<sup>2</sup> Present address: Department of Physiology, University of Queensland, Brisbane, Australia.

Practically encircling the island, never distant from the coast-line, is a belt of dense forest containing many beautiful trees.

Much of the early prehistory of Madagascar is an enigma. Du Toit ('37) reflects Selater's views (1864) that the island constituted a part of Africa and was connected with India in the Tertiary. During the Permian, a trough — the forerunner of the Mozambique Channel (now only 160 miles wide at its narrowest point) — developed. The Miocene produced minor submergences, and the break represented by the Oligocene suggests that Madagascar became re-united to Africa temporarily thus explaining the well-established faunal relationships that are exemplified by the lemurs, monkeys, tortoises, pygmy hippopotami, etc. (Gregory, '21). The whole problem of land-links and land-migrations is still a controversial issue but there can be no doubt that there are distinct relationships between the fauna of Madagascar and that of Africa and Asia, but Madagascar contains none of the typically later African antelopes, equids, elephants, rhinoceroses, giraffes and large carnivores (lion, leopard, jackal, etc.). This absence of the larger carnivora and ungulates points to the separation of Madagascar from the mainland before the latter was overrun by these larger mammals and at a time when its chief mammals were lemurs and insectivores. Several peculiar genera of these animals are found extensively in Madagascar.

The largest living wild terrestrial animal in Madagascar is the wild boar (*Potamochoerus edwardi*) while the rivers are infested with African crocodiles. Known historically are the Pygmy Hippopotamus (extant only in West Africa at present), the giant wingless bird (*Aepyornis*) whose egg was the largest ever described (12" by 9") and giant lizards. The largest of the Malagasy carnivora is the "Fossa" or "Foussa," *Cryptoprocta ferox*, which is peculiar to the island. It is about twice the size of the common cat (5 ft. from nose to tip of tail) with short close fur of nearly uniform pale brown. The commonest quadrupeds on the island are shorthorn Zebu cattle and, to a lesser extent, the

Sanga breed. There are more than 4 million cattle on the island which are hardly ever milked and only slaughtered for feasts on the death of their owners.

One of the most exciting faunal features of Madagascar is that by far the large proportion of species of the *Lemuroidea*, including all those to which the term "Lemur" is now specially restricted, are exclusive inhabitants of the island where they are phenomenally abundant and widely distributed. From Madagascar as a center a few species less typical in character extend through the African continent westward as far as Senegambia, and others are found in the Orient as far east as the Philippine Islands. In Madagascar too, have been found the only remains of the extinct gigantic lemuroid genus, *Megaladapis*. Of the extant lemuroids, the family *Chyromyidae* is represented only by a single species, *Chiromys madagascariensis*, the aye-aye, a nocturnal animal first discovered by Sonnerat in 1780.

## 2. History and problems

The literature on the origin of the 4 million people of Madagascar (the Malgache or the Malagasy) goes back to the 16th Century. Much of it was written in more leisurely ages when a man could elaborate a small point over many pages, and the result is a bulky mass of repetitions, often difficult to lay hands on today, and virtually all based on a few spectacular and unique features which strike every visitor to the island.

No attempt is made here to review in detail the previous literature on the subject. Instead, we have endeavoured to present the salient points as they appeared to us after much reading and digestion. For those who seek more detailed information a list of references is appended which contains the most important works of which many in themselves are detailed reviews and discuss at great length the numerous hypotheses built up to explain the strange findings on Madagascar.

There are a number of reasons why theories of the origin of the Malagasy have flourished in the past and may well continue to do so in the future. The language of the island was unwritten until the advent of European missionaries during the middle of the last century and the only extant records are found in a few manuscripts in Arabic which deal with the history of the alleged Arabian ancestor of a tribe called Zafiramanina inhabiting the district round Mananjary on the south-east coast. The traditions carried down by word of mouth are almost confined to the Hova. It is possible from these traditions to establish a sequence of some 37 Hova rulers which when taken back in time, leads to about the tenth century, at which time the Hova traditionally arrived from the East coast or possibly from across the sea.

There are no ancient monuments on Madagascar depicting the physical character or mode of living of past people. Physical anthropological research on any reasonable scale can only be carried out on the living, as to this day, and in spite of virtually the whole population being nominally Christian, the cult of the dead remains one of the strongest spiritual forces on the island.

There are certain indisputable premises which must be and have been taken into account by all propounders of hypotheses. The very first explorers observed that the Malgache language was either descended from or had the same origin as the Malayo-Polynesian languages. As the exploration of the island continued another astounding fact emerged: from North to South, from East to West the whole population spoke a single language. Subsequent philological studies have shown the presence of some Sanskrit elements in Malgache; astrological words are of Arabian origin; and some important terms like those for several domestic animals are derived from Bantu words. Not only the language, but the way of living of the Malagasy is that of the Eastern archipelagos. Rice culture, utensils, clothing, housing, musical instruments, totem poles, beliefs and superstitions came from the East and not from the much closer continent of Africa. It was

clearly difficult for previous observers to believe it possible for large numbers of people (including women) to traverse the Indian Ocean in flimsy boats and one finds curious calculations attempting to show that 500 couples might become 1,024,000 people in 500 years to explain this difficulty. Historical evidence of this type of maritime enterprise is, however, overwhelming (Hornell, '34). The last puzzle which confronted the European savants from the earliest days was obvious mixture of races in a people speaking but one language. Already in 1550, Nagnort stated:—"There are two types of inhabitants; the ones black with frizzy hair who are the original people of the country; the other white with long hair who came from the coast of Persia 500 years ago." All reliable subsequent reports confirm the observation, which is quite evident to this day, that in virtually any tribe on the island one finds these two types and any mixture of the two. It is true that in the Imerina the light skin and straight hair is more evident and that among, for instance, the Bara the negroid type predominates, but no reliable author has ever maintained that it is possible to detect from the appearance of one individual the region from which he originates. The unity of language and the variability of physical characters have been factual stumbling-blocks for all theorizers of the origin of the Malagasy.

Two points of a much more contentious nature stand out in the literature, old or new: firstly, were there any people on Madagascar before the arrival of the Indonesians? And secondly, is the negroid element on the island of African or Oceanic origin, and if African when did it arrive? The basis of the first question is the presence on the island of old traditions of autochthonous populations met and suppressed by the expanding Indonesians. These were the Vazimba on the high plateau and the Kimosy towards the south. There seems little doubt now that the Vazimba cultivated rice and that their language was little different from that of the invading Hova so there is scant reason to believe that they were autochthonous although they may have arrived in earlier migrations



from Indonesia than those people among whom the tradition of their existence arose. The legends with regard to the Kimosy are vague and contradictory. They were supposed to be of dwarfish stature with light brown skin and woolly hair. They have variously been considered Bushmen or Pygmies, Negritos or achondroplasias, but until definite skeletal evidence is produced there is no real reason to believe in their existence at all. It is quite conceivable that Madagascar was uninhabited until the arrival of the Indonesians, just as Mauritius and Réunion were when the Europeans first came there. It is significant that no stone implements have yet been found on Madagascar.

As far as the second problem is concerned it may be said that the evidence for the Oceanic origin of the accepted negroid element on the island is scanty. It is based on the allegation that some of the negroid types are distinctly different from Bantu and cannot be explained by mixture with the rest of the population, an allegation which few physical anthropologists would accept. Secondly, the scarcity of Bantu (including Swahili) words in Malgache is mentioned as *evidence*. There is, on the other hand, satisfactory historical proof that slave traffic between Africa and Madagascar took place from at least the 12th century until the end of the 19th, and there is somewhat less satisfactory linguistic evidence that Sumatrans first arrived in Madagascar, and presumably therefore also on the East coast of Africa, in the 2nd Century A.D., so there is no real reason for stipulating other than an African origin for the negroid population on the island. Slaves are automatically forced to adopt the language of their masters and in other parts of the world, for example in South America, no trace of African words has survived, although nobody doubts the considerable negroid admixture in the population.

In spite of the unshakable evidence of a centuries-old traffic between Africa and Madagascar even quite recent workers (Ratsimamanga, '40) maintain that the bulk of the negroid element is Oceanic in origin. The contention is based partly on studies of physical character, but mainly on a sur-

vey of the distribution of the so-called "Mongolian spot" in the population. It appears doubtful that this rather vague pigmentary phenomenon can be used to differentiate the racial elements in a hybrid population, and when it is finally brought up as evidence for the common origin of all Negroes, one lands certainly in pure conjecture.

Another fairly recent work (David, '40) is based on a survey of the ABO blood group system with physical anthropology as supporting evidence. A complex working hypothesis is built up which virtually embraces all previous suggestions beginning with an autochthonous population of Pygmies which was destroyed by a massive negroid invasion from Africa. This in turn was followed by an Indonesian (Oceanic) period which gave rise to the Vazimba. The fourth period was that of mongoloid people from Malaya which mixed with the black population and eventually gave rise to the Hova of modern times. It also fits in the Arabian infiltration for which, however, the evidence is mainly ethnological. It is only fair to say that the author of this scheme was fully aware of its tentative nature, and it will certainly not stand up to critical analysis.

In summary it may reasonably be stated that only by the collection of new facts will progress be made in solving the enigma of Madagascar. The most promising avenues seem to be the discovery of written records outside Madagascar as was so promisingly commenced by Hornell ('34), and the application of new genetical knowledge such as the many new blood group systems and the ever expanding hemoglobin series. It is with a very incomplete and preliminary survey of the last systems that this report deals, supported as usual by a study in physical anthropology.

#### METHODS AND MATERIALS

In July 1954, Drs. Budtz-Olsen and Singer flew to Madagascar. Owing to the short duration of this visit, the large numbers examined in that time, and to the fact that only one

(R.S.) was studying the physical characteristics as well as assisting in the hematological investigations, a system of rapid examination was devised, which, though non-metrical except for measurement of stature, was designed to give a reasonable impression of the physical appearance of the groups based on subjective standards of comparison. Mimeographed sheets were made on which were placed headings: name, age, sex, tribe, height, and the main facial features. A "shorthand" method was used to record the observations (see symbols on table 1). Although it may be said that this method is essentially useless, in the hands of a trained observer who is thoroughly acquainted with and has made numerous similar surveys on associated racial groups it may be a useful method for a basis of comparison. Occasional errors would tend to be "smoothed out" in a large number of observations.

A sample of hair from each individual examined was collected and sent to Professor Mildred Trotter, Washington University, St. Louis, who has kindly agreed to examine and to report on them separately. Specimens of blood were sent to Dr. Reuben L. Kahn, Serology Laboratory, Ann Arbor, Michigan, for his Universal Serum Reaction survey.

Half the sample was tested for sickling by the classical sealed-coverslip method with examination after 24 and 48 hours; the other half by the sodium metabisulphite method of Daland and Castle ('48). The two methods gave the same incidence of sickling in the Merina, the largest sample examined by both methods.

Blood for grouping and electrophoresis was collected in the sterile glucose-citrate-merthiolate solution of Simmons et al. ('51). Electrophoresis was performed as described elsewhere by Brain ('55b).

#### PURPOSE OF THE STUDY

The primary purpose of this study was to determine the incidence of the sickle-cell phenomenon in Madagascar. In the continent of Africa the distribution of the sickle-cell shows certain very remarkable features (Raper, '50; Lehmann, '54;

Neel, '51; Singer, '53; Brain, '53, '55a; Budtz-Olsen and Burgers, '55), which may be summarized thus: it is found both among the West African Negroes and the Bantu of Central and Southern Africa. Its highest incidences occur nearer to the East coast than the West, but its distribution in Bantu tribes of Central Africa is very patchy, and perhaps the most remarkable feature of all is the very sudden decrease in sickling incidence amounting to virtual absence in all Bantu tribes south of the Zambezi River. As a result of finding the sickle-cell trait in aboriginal hill tribes of Southern India, Lehmann and Cutbush ('52) suggested that the sickle-cell trait might be a recent importation into Africa, which had arrived at a time after the black races had established themselves; they stated that Veddian peoples from the East might have brought it to Africa through South Arabia and across the southern end of the Red Sea (Lehmann, '53). A comparatively recent migration of this kind would account for the observed irregularity of the sickle-cell trait distribution. Brain ('53, '55a), from a study of sickling incidence in Bantu tribes on both sides of the Zambezi River, suggested that there was a significant parallel between the distribution in Africa of the sickle-cell and that of the shorthorn Zebu breed of Indian cattle. The shorthorn Zebu is known to have been introduced into Africa through Southern Arabia and across the southern end of the Red Sea comparatively recently; estimates vary between 400 B.C. and 700 A.D. with the latter ones almost certainly the more likely (Bisschop, '37; Dart, '51; Curson and Thornton, '36). It is found among both the West African Negroes and the Central African Bantu, and, like the sickle-cell, it does not occur south of the Zambezi River. We have thus, in the sickle-cell and the shorthorn Zebu, two things which were introduced from the East by the same route, in about the same historical period, and which to this day have almost identical distributions in the African continent. Brain ('53) suggested that the sickle-cell was in fact brought to Africa by the human migrants from Asia who distributed the shorthorn Zebu in the course of their wanderings. At the time

when this view was put forward nothing was known of the sickling incidence in Madagascar, but it was clear that it would be of the greatest interest. Although the population of Madagascar is ethnologically and linguistically Indonesian rather than African the dominant breed of cattle is the shorthorn Zebu which was taken over by sea from Africa at some point north of the Zambezi River mouth (Bisschop, '37). If the Malagasy population were to be shown to contain an appreciable proportion of sickle-cell trait bearers some confirmation would be provided for the theory coupling the sickle-cell and shorthorn Zebu migrations.

## RESULTS

### 1. *Physical characteristics of the tribes*

Some of the tribes and smaller units are grouped either according to Ratsimamanga's ('40) classification or to historical association. Not included in the table are those tribes represented only by one or two subjects in our survey. The geographical distribution of the tribes are shown in figure 1.

The similarity of many of the tribes is very evident but it can be seen, for example, that in respect to the features studied, the Merina are less negroid than the Bara in whom there is a definite uniformity of type. But those of the latter studied were a group selected originally for military purposes and for political reasons, so that the comparison may not be absolutely accurate. As a guide to table 1, one could represent a "typical" negroid and a "typical" mongoloid as:

	HAIR	LIPS	EYES	NASAL WIDTH	NASAL BRIDGE	NASAL ALA	MOUTH	PROGNA- THISM	SKIN COLOR
Negroid	2+	2+	+	2+	+	2+	+	+	3+
	or	or	or			or	to	or	or
	3+	3+	2+			3+	3+	2+	4+
Mongoloid	—	+	2+	+	—	+	+	—	+
			or	or		or	or		
			3+	2+		2+	2+		



*Key to tribes:*

- |                           |                       |                   |
|---------------------------|-----------------------|-------------------|
| 1. Sakalava               | 10. Bara              | 19. Betsimisaraka |
| 2. Antakara               | 11. Mahafaly          | (Southern group)  |
| 3. Tsimihety              | 12. Antandroy         | 20. Betanimena    |
| 4. Scattered mixed groups | 13. Antanosy          | 21. Betsimisaraka |
| 5. Sihanaka               | 14. Antaimanam-bondro | (Northern group)  |
| 6. Merina                 | 15. Antaisaka         | 22. St. Marie     |
| 7. Bezanozano             | 16. Antaifasy         | 23. Comorians     |
| 8. Betsileo               | 17. Antaimoro         |                   |
| 9. Tanala                 | 18. Antambahoaka      |                   |

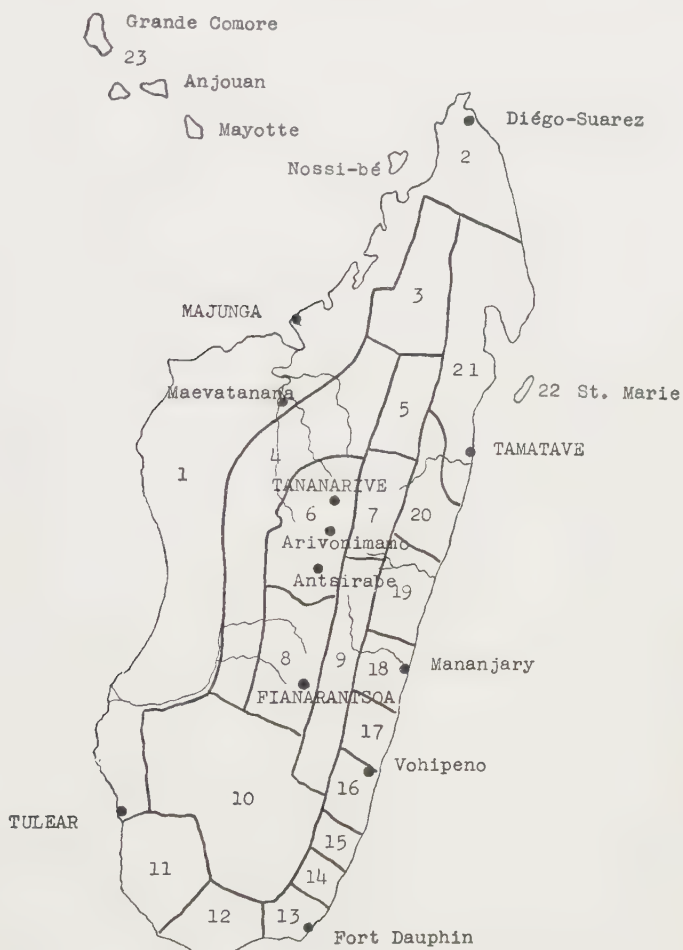


Figure 1

TABLE 1a

TRIBE	HAIR			LIPS			EYES			COLOUR					
	-	+	2+	3+	+	2+	3+	+	2+	3+	4+	+	2+	3+	4+
Merina (247)	26	36	38	..	70	28	2	45	55	..	46	31	22	1	
Comorian (108)	10	11	71	8	58	41	1	42	55	3	14	6	41	39	
Sakalava (72)	7	19	70	4	47	51	2	53	46	1	4	17	37	42	
Masikoro (2)															
Vezo (5)															
79															
Betsileo (64)	23	18	59	..	45	53	2	53	47	..	11	14	47	28	
Tsimihety (32)	9	9	82	..	41	53	6	53	47	..	19	28	44	9	
Bara (28)	4	7	89	..	29	71	..	68	32	..	..	7	29	64	
Sihanaka (13)	20	16	64	..	36	56	8	48	52	..	24	8	48	20	
Betsimiseraka (10)															
Bezanozano (2)															
Antaimoro (2)	4	38	58	..	8	92	..	65	35	.	4	11	54	31	
Tanala (1)															
Antanosy (10)															
Antandroy (8)															
Antaisaka (5)															
KEY:															
	— Straight			+ Thin			+ Non-			+ Light brown					
	+ Long and broad waves			2+ Average thickness			Mongoloid			(whitish or yellowish brown)					
	2+ Very curly to crinkly			3+ Thick and everted			2+ Elongated, slightly slanting, walnut shaped			2+ Brown					
	3+ Peppercorn						3+ True			3+ Dark brown					
							Mongoloid (slanting, epicanthic			4+ Black					

TABLE 1b

TRIBE	NOSE										MOUTH		PROGNATHISM	
	Width		Bridge		Alae									
	+	2+	-	+	2+	+	2+	3+	+	2+	3+	-		+
Merina (247)	81	19	78	22	..	1	86	13	26	74	..	29	62	9
Comorian (108)	96	4	87	13	..	..	99	1	29	62	9	22	58	20
Sakalava (72)	99	1	90	9	1	2	93	5	22	76	2	15	63	22
Masikoro (2)														
Vezo (5)														
79														
Betsileo (64)	93	7	83	17	..	..	93	7	25	72	3	12	66	22
Tsimihety (32)	94	6	78	22	..	..	94	6	6	91	3	6	66	28
Bara (28)	100	..	89	11	..	..	82	18	32	61	7	14	72	14
Sihanaka (13)	88	12	80	20	..	..	84	16	20	80	..	16	44	40
Betsimiseraka (10)														
Bezanosano (2)														
Antaimoro (2)	100	..	92	8	..	..	85	15	27	73	..	15	65	20
Tanala (1)														
Antanosy (10)														
Antandroy (8)														
Antaisaka (5)														
KEY:	+	Average	—	Flattened	+	Normal	+	Average	—	Orthognathous				
	2+	Very wide	+	Raised	2+	Dilated and flattened	2+	Wider than average	+	Alveolar prognathism				
			2+	Raised and hooked (Armenoid)	3+	Dilated and everted	3+	Markedly wide	2+	Markedly prognathous				

Naturally, in assessing these tables, one has to be wary of the pitfalls present in depicting "typical" racial pictures, of the nature of overlapping at the extremes of these definitions and of the occasional individual errors. One must recognize, for example, that many negroid types have thinnish or average-thick lips and "eastern" eyes (slightly narrowed and sloping with "smooth" upper lid — *vide infra*) while a mongoloid may have thick and everted lips, and so on.

The following are notes on the various tribes examined. The small numbers examined do not permit accurate statistical conclusions so that reference should be made to table 1 for comparisons. However, the Merina, Comorians, and Sakalava are discussed in fair detail. The observations are generally in agreement with those of Ratsimamanga ('40) who studied much larger numbers, but whose interpretations are not acceptable. Various authors' views of the racial constitution of the tribes are mentioned only to indicate the confusion of opinions existing at present.

1. *Merina*. The "People of the Highveld" occupy the Merina Province of the central highlands and number more than 1.4 million. Popular tradition considers them the descendants of an intermixture between the Vazimba (legendary dwarfs), the Javanese and the Malays, while some consider them direct descendants of the Vazimba only. The Merina may be divided into three major groups:

1. Andriana, or nobles.
2. Hova, or "free men" (commoners).
3. Mainti, or Mpanompo, or Andevo — the slaves.

There are two categories of slaves: (a) those of recent importation from Africa, known as Mozambiques, and set free in 1877, and (b) the Tsierondahy and Manaisotra who are reputed to be primarily Oceanic negroes who also have characteristics of the Betsileo and Sihanaka. The latter used to be the serfs of the royal castle and served as bodyguards.

Dubois (quoted by Ratsimamanga) found typically negroid individuals among the higher castes.

Our impression was that the Merina formed the best educated section of the population, and they occupied most of the clerical, professional and higher salaried native officials' posts.

Nearly all the Merina examined were Hova, and although most were brachycephalic, quite a fair number were mesati-cephalic or dolichocephalic. They tend to have rather high, rounded foreheads (fig. 2). Nearly 40% of the 247 examined have a crinkly type of hair, while 26% have straight hair. None had the "pepper-corn" type (rounded clumps of tightly spiralled hairs somewhat separated from each other). About 80% had an average width of nose and the same number had a flattened nasal bridge as well as flattened, dilated alae. Thirteen per cent had alae which were distended and everted.

"True" mongol eyes — slit-like, markedly slanting with an epicanthic fold — were not seen, but just over half had a type of almond-shaped eye, commonly seen in Malays and Indonesians, and also in some Bantu-speaking negroids, in whom the upper lid is smooth and gives a "sleepy-eye" effect, emphasized by a slight slant produced by slightly elevated malars: this type of eye is here referred to as "eastern-type" (see fig. 2).

Seventy per cent had thin lips and only 2% had the very thick everted lips sometimes associated with the negro. Over 70% exhibited varying degrees of prognathism, while the Merina also had the highest percentage of orthognathous individuals of all the groups examined.

Nearly half the number were light brown in color and only 22% were black.

2. *Comorians*. Although not Malagasy, these migrants have close ties with the north-western populations of Madagascar, being mainly of Arab, African and Indian origin, many of whom have admixed freely with the north-western tribes.

There is a tendency towards dolichocephaly but most of the subjects examined were children. They have the highest incidence (8%) of all tribes examined of pepper-corn hair. Seventy-one per cent had crinkly or very curly hair, only 10% had straight hair, and the remainder had long wavy hair.



Only 4% had a broad flattened nose while the remainder had a nose of average width (by European standards). In 87% of cases there was a depressed type of nasal bridge, and less than 1% had dilated, everted alae.

More than half (55%) had the "eastern" almond-shaped eye, while 3% had typical Mongoloid eyes.

In almost one-third the mouth is of average width while in 62% it was fairly wide and in 9% very wide. Nearly 60% had thin lips and only about 1% had thick everted lips.

About 20% were orthognathous and the remainder exhibited varying degrees of prognathism, which was marked in about 20%.

The majority of the Comorians were very dark, about 40% being dark brown and a further 40% being black, while only 14% were light skinned.

3. *Sakalava* (fig. 3). The name means "Those of the Long Valley," and these quarter-of-a-million Malagasy include all the tribal groups of the west coast from Nossi Bé to Tulear. They tend to be warlike and have on previous occasions assisted the conquering Hova, and it is said that they make some of the best troops on Madagascar. Many of the women decorate their faces with paint and wear sari-like clothes and silver chains, beads and filigree ear-rings. It is generally considered that they are mainly of African (Bantu) origin, although Dandouau, quoted by Ratsimamanga, considers them to be the descendants of an autochthonous race and a sub-tribe of the Antaisaka who he considers are a mixture of Arabs and Indians. Rusillon ('18) on the other hand, considers them to be of Indo-Melanesian origin with subsequent admixture of Arabs and Europeans.

The Sakalava may be divided into two main groups: the Masikoro (Masokoro) of the interior (*vide infra*), and the coastal Vezo who are fishermen, sailors and accomplished swimmers. In general, both usually refer to themselves as "Sakalava."

There was no trouble in collecting 79 cases in a very short time only two of whom identified themselves as Masikoro and 5 as Vezo. The "obstruction to examination" which Ratsimamanga complains of in collecting only 60 cases was not encountered.

They are mainly dolichocephalic and have sparse distribution of facial and body hair. About 70% have crinkly hair, 4% have a pepper-corn type and 27% have straight or slightly wavy hair. Almost 60% have thin lips and only 1% have thick everted lips, while about 80% have mouths wider than average and 3% have markedly wide mouths.

Less than half (45%) have the "eastern type" of eye and only 1% have true mongoloid eyes.

More than 90% have a flattened nasal bridge, almost all have an average width of nose and in 94% the alae are dilated and flattened. More than one-quarter of the Sakalava examined have marked prognathism and nearly 60% exhibited alveolar prognathism.

With 42% being black, they are second only to the Bara in having the highest incidence of this skin color.

The Makoa, who number about 56,000 are certainly known to be the direct descendants of black slaves who originated in Africa, north of the Zambezi River. Only two were examined in our survey and they have been included with the Sakalava among whom they lived.

4. *Masikoro*. These 13,000 form a sub-group of the Sakalava. They are in the main soil-cultivators, and occupy part of the west coast situated around Tulear.

5. *Betsileo* (fig. 4). These half-a-million people occupy the southern part of the high central plateau. All previous writers have described them as predominantly negroid. Belloy ('09) studied them metrically and considered them a type intermediate between the Negroes and Malays. Some authors described the ancestors of the Betsileo as African Negroes. These opinions are usually not based on studies of any sort and carry with them all the dangers and errors of presenting

conclusions of racial diagnosis based on the superficial appearances of a few people. Even Ratsimamanga states that the appearance of some Betsileo approximate them to the Merina slaves (Tsierondahy and Manaisotra) and some resemble natives of the extreme oriental population, while a few remind him of the Moïs of Indo-China.

Ratsimamanga states that he found two main types: (1) Light skinned with nose hardly flattened and thin lips — rare, and, (2) very dark skin, nose flattened and thick lips.

It is here contended that every tribe could be more or less thus divided, and, like all genetic crosses, in some type (1) predominates, while in others type (2) is more common, and there are many in between.

6. *Tsimihety* (fig. 5). The tribal name means “those that do not use the scissors” (i.e. to cut their hair). The origin of these 207,000 Malagasy who occupy the northwest coast is very obscure. Dandouau considers them to be a product of the mixture of immigrants who have come from the Betsimisaraka area and from the Tanala. He also considers that a great number originate from the slaves of the high plateau.

7. *Bara*. These occupants of the region south of the Betsileo country number 160,000. Verneau considers them pure African negroes while Le Barbier considers them Oceanic negroes (both quoted by Ratsimamanga). Ratsimamanga describes them as dolichocephalic (C.I. 76), tall and thick-lipped. He states that they look surprisingly like Neo-Hebridians and Cameroonians, which “fact” leads him to believe in the single origin of all negroes!

The 28 examined produce the most homogeneous results of our survey. Most have crinkly hair, fairly thick lips and a rather wide mouth. A third have somewhat slanting eyes, though not apparently elongated. None have a very wide nose, though nearly all have dilated flattened alae and some of which are even everted. The majority are prognathous and black (highest incidence in the survey) while a third have a very dark brown skin.

8. *Sihanaka (or Sianaka)*. The "Lake People" number 65,000 and occupy the region between the Imerina and Tsimihety. Grandidier ('08) considers these agriculturalists to be of Indian origin. Ratsimamanga states they have mixed much with the Betsimisaraka, who are the Malayo-Polynesian negroid type, and also with the Hova and that they are not very different from the Vazimba (who are the mythological dwarf ancestors). Rusillon considers them to be Indo-Chinese mixed with Oceanic negritoes and Papuans. According to Dubois and the majority of authors, the Sihanaka are short and black with crinkly hair, low foreheads and flat noses.

Because of the smaller number examined by us and because of the obvious tribal affiliations we lumped together the Sihanaka with the Mahafotsy, the Betsimisaraka and the Bezanozano, producing a total of 25 individuals.

9. *Betsimisaraka* (fig. 6). "The Inseparables" number 480,000 and live along the east and northeast coast. They are said to supply the greatest numbers of laborers on the island. Ratsimamanga describes them as black-skinned with low forehead, flat nose and with hair "crinkly in some and straight in others." However, he noticed a great divergence of physical type in their territory.

10. *Bezanozano*. "The people with the small tresses" number 28,000 and live in the region between the Imerina and the Sihanaka. Ratsimamanga states that they are partly of African origin and partly derived from Betsimisaraka. He describes them as dolichocephalic, with yellow-brown skins, a straight forehead, non-slanting eyes and hair nearly straight. The Bezanozano are pastoral cattle farmers.

11. *Antaimoro (or Antaimorona)*. The tribal name means "those on the coast." They number almost 180,000 and occupy the southeast coast around Vohipéno. Ratsimamanga considers them to be of Arabian origin and they write the Malgache alphabet with Arabian letters. He considers the Tanala and Antaifasy as sub-groups; however, on the same page in his publication he describes the Antandroy, Antaifasy and Tanala as groups distinct from the Antaimorona.



It has here been decided to consider these 4 and the Antanosy and Antaisaka as one group, totalling 34 individuals.

Grandidier classified the Antaimoro as representative of those types who exhibited dolichocephalic heads with long faces, nearly orthognathous, straight forehead, pointed chins, and scanty beard and hair on the body.

12. *Tanala*. "The people of the forest" number between 150,000 and 190,000, and, as the name suggests live in a rugged mountainous region with heavy rain forests on the east coast between the Mangoro River mouth and the Mananara River. This area has acted as a refuge for those driven from better lands on the coast or inland. According to tradition (Linton, '43) when the ancestral Tanala entered the territory 10-14 generations ago, they found it already occupied by two groups who differed markedly from themselves in both culture and physical type. The southern group, the Teroandroka, are said to have been very short and of slight build, like immature boys. Their skin was very dark, almost black, and they had short kinky hair, round faces, and strikingly round staring eyes. They were hunters and food gatherers with no fixed abode and had no gens totems. They were a timid people who offered no resistance to the invaders who absorbed them. Apparently there are still a few Tanala gentes who conform to this physical type and Linton states that they lack the extreme negroid characteristics of African pygmies but could readily be mistaken for Oceanic Negritoës. But it is hardly likely that they would have persisted as a "pure" unmixed type throughout this long period of time. The northern group of aborigines, the Zanakanony, seem to be more clearly remembered. They were also short (5'-5'4") but more powerfully built with deep chests and heavy muscles, very light in skin color and had long wavy or at most curly hair. They lived in caves and in small lean-tos thatched with large leaves. They had neither chiefs nor slaves and lacked gens totems. They spoke a language intelligible to the Tanala.

In one author's opinion (R.S.) the basis of these traditional ancestors may be one of the pygmy type of Malay admixture



from southeastern Asia or Malaysia (Jacobs and Stern, '50) who may have formed part of the early migratory groups to Madagascar. The tradition of ancestral dwarf types seems to be common in many tribes all over the island (e.g. the Vazimba), but with a historic episode of Malayo-Indonesian migration of peoples who may have contained many "pygmy" or short individuals or groups, their shortness of stature may have become accentuated, and, attributed with a sinister aura by the relatively tall modern population, they may even have become ostracized.

13-15. *Antandroy, Antaifasy, Antaisaka and Antanosy.* These number between 200,000 and 250,000 people who occupy the southern regions of Madagascar. Rouquette (quoted by Ratsimamanga) examined 700 of the Antandroy, Antaifasy and Tanala tribes and considered them to be "like the Neo-Caledonians."

Dandouau, writing of these three tribes, states that traditionally they have their origin in two autochthonous tribes which were conquered by tribes of Indian origin in the 15th Century. Grandidier described the members of these three tribes as somewhat small-headed, tending towards dolichocephaly, with flat oval faces, flattened noses, thick lips, prominent cheek-bones.

Ratsimamanga states that the Antandroy (of whom there are 170,000) correspond to the Oceanic type and are probably closely related to the residual Negro population of the extreme Orient. Arabic types are rarely found, and their way of life is primitive and not at all Arabic and they can be described as bordering on the food collector state.

The Antaifasy still use Polynesian-type dug-outs with a prow and also flat-bottomed ones. They have been described as possessing crinkly and wavy hair which they keep in tresses, some with thick lips and some with thin, slant-eyed and some with dilated nostrils, with fairly good beards and moustaches!

The Antaisaka have been described as well-built and tall, broad-nosed and prognathous. They possess cone-shaped fish-

baskets of a type which are also found in the Congo, Egypt and Sweden.

16. *Antakarana*. "Those of the rocky country" number 50,000 and none have been encountered in this survey. They raise cattle in the region of Vohémar. They have very crinkly hair, flat nasal bridges, broad-noses and thick lips. Some have small alae and small mouths. The women wear saris and have fancy filigree ear-rings and some have decorations in the alae of their noses (a not uncommon finding in many tribes). Their culture is said to have marked Arabic and eastern influences, and they are said to have a Nilotic or Negro appearance.

## 2. *Universal serologic reactions*

Doctor Reuben L. Kahn of the Serological Laboratory of the University of Michigan kindly tested the 28 specimens which we were able to send him. One of the authors (R.S.) had also previously sent him specimens of South and Central African Bantu and Cape Coloreds so as to assess whether there was a significant racial difference in these reactions. As yet the numbers tested are too small to draw specific conclusions (table 2).

TABLE 2

### *Universal reactions in different peoples*

	STRONG	MODERATE	WEAK
Mid-Western Americans (100)	5	10	85
Cape Colored, So. Africa (11)	4	5	2
Bantu-speaking Negroids, East, South and Central Africa (74)	22	35	17
Malagasy of Madagascar (28)	13	4	11

The universal reaction is a biologically universal response. It is universal in the sense that all persons tested have been found to give positive reactions, although the degree of reactivity given by different persons may differ considerably. The reaction is believed to be a lipid antigen-antibody reaction, and in the universal serologic technique, Kahn antigen is employed. The universal technique differs from serodiagnostic

techniques for syphilis, and is therefore not to be associated with these techniques.

The nature of the universal reaction is not yet fully understood. Kahn believes that it might be associated with catabolism. Briefly, certain lipids liberated in normal tissue catabolism undergo chemical changes or conjugations which cause them to become foreign to the body and auto-antigenic. These antigenic lipids call forth the formation of auto-antibodies which are detected by the universal serologic reaction.

American Indians have been found to give higher percentage of strong or moderately strong reactions than peoples living in the midwestern part of the United States. The reactions are considerably stronger in the entire African group as compared with the results given by midwestern Americans.

If one divides up the few Madagascar results (table 3) into Merina and non-Merina the distribution in the concentration is approximately the same, but two very strong reactions appear in the non-Merina group only.

TABLE 3  
*Universal serologic reactions in the Malagasy tribes*

	WEAK	MODERATE	STRONG
Merina	7	2	6
Betsileo	1	..	3 <sup>1</sup>
Betsimiseraka	..	..	1
Masikoro	2	..	1
Bara	..	2	2 <sup>1</sup>

<sup>1</sup> Includes one very strong reaction.

### *3. Sickling and serology*

It was our purpose to ascertain whether the Malagasy, who own about 4 million shorthorn Zebu, possessed the sickle-cell. At the same time we took the opportunity to investigate several other physical and serological characters. Whenever possible the tribal affiliations of the parents of each individual were ascertained. Although the northwest tribes contain elements from the neighboring Comoro Islands, when both parents are Comorians these are classified separately.

TABLE 4  
*Hemoglobin S (sickle-cell hemoglobin)*

TRIBE	NO. EXAMINED	NO. SICKLING	% SICKLING
Merina	1004	33	3.3
Betsileo	130	6	4.6
Sakalava	90	10	11.1
Betsimisaraka	47	3	6.4
Sianaka	45	3	6.7
Tsimihety	43	7	16.2
Bara	37	4	10.8
Vakinankaraka	26	0	
Antandroy	22	0	
Bezanozano	19	1	
Antaisaka	14	2	
Antaimoro	13	0	
Antanosy	11	1	
Tanala	7	3	
Others	38	3	
Totals for Madagascar	1546	76	4.9
Comoro Islanders	126	6	4.8

*Other abnormal hemoglobins*

No other abnormal hemoglobins were found in 363 specimens which were comprised of 186 Merina, 29 Sakalava, 34 Betsileo, 8 Betsimisaraka, 7 Comoro Islanders, 4 Sianaka, 27 Tsimihety, 11 Antanosy, 27 Bara, and 30 others.

*Blood groups*

The numbers examined are too small to allow classification by tribe, and the subjects have been divided simply into Merina and non-Merina.

TABLE 5  
*ABO groups*

NUMBER EXAMINED AND TRIBE		PHENOTYPES (%)				GENE FREQUENCIES		
		O	A	B	AB	p	q	r
Merina	157	41.4	26.1	25.5	7.0	.1793	.1755	.6460
Non-Merina	156	48.7	20.5	27.6	3.2	.1327	.1742	.6940
TOTAL	313	45.1	23.3	26.5	5.1	.1545	.1745	.6700

TABLE 6  
*Rh groups*<sup>1</sup>

NUMBER EXAMINED AND TRIBE		USING ANTI-C, ANTI-D AND ANTI-E						USING ANTI-C AND ANTI-D ONLY		
		CD <sub>Dee</sub>	cc <sub>Dee</sub>	cc <sub>DE</sub>	Cd <sub>dee</sub>	C <sub>DE</sub>	cc <sub>ddee</sub>	CD	cc <sub>D</sub>	C <sub>dd</sub>
Merina	95	29	29	1	0	5	1	30	0	0
Non-Merina	75	11	16	5	0	1	3	28	10	1
TOTALS	170	40	45	6	0	6	4	58	10	1

<sup>1</sup> All specimens were examined with anti-C and anti-D sera and many with anti-E.

On the basis of the totals the reactions without anti-E were proportionately allocated as follows:

58 CD allocated as 50 CD<sub>Dee</sub>, 8 C<sub>DE</sub>

10 cc<sub>D</sub> allocated as 1 cc<sub>DE</sub>, 9 cc<sub>Dee</sub>

1 Cd allocated as Cd<sub>dee</sub>

The totals then become:

	CD <sub>Dee</sub>	cc <sub>Dee</sub>	cc <sub>DE</sub>	Cd <sub>dee</sub>	C <sub>DE</sub>	cc <sub>ddee</sub>	C <sub>ddE</sub>	TOTAL
Number observed	90	54	7	1	14	4	0	170
Per cent	52.90	31.79	4.12	0.59	8.24	2.35	0.00	

The chromosome frequencies are:

c <sub>De</sub>	.4308	c <sub>DE</sub>	.0640
C <sub>De</sub>	.3253	C <sub>dE</sub>	.0567
c <sub>dE</sub>	.1532	cd <sub>E</sub>	.0000

The Merina have not been separated because of the small size of the sample, but calculations for them give a similar result (0.44) for the *cDe* chromosome. Because of the small size of the total samples, and the inaccuracy involved in allocating the results obtained without anti-E, the results above are only approximate.

## DISCUSSION

### 1. Physical characteristics

The authors are in full agreement with Linton ('43) that Madagascar today provides ample evidence for the belief



that there is no intrinsic or necessary relationship between language, culture, and physical type. The Malgache language is singularly uniform throughout the island; the cultures, though less uniform, have many basic elements in common; and, the physical types form a sliding scale of varying mixtures of Caucasoid, Mongoloid and Negroid affinities.

Hazardous as it is to draw conclusions from a small number of non-metrical observations on a small percentage of the population and that not in equal distribution among the tribes, it is even more dangerous to attempt what Ratsimamanga has done, namely to estimate the percentage of Mongoloid, Europoid, Oceanic-Negroid and African-Negroid features in each tribe on a basis of hair type, skin color, cephalic index and the incidence of the Mongolian spot. In addition he estimated the percentages of representation of these 4 groups in the total population and concludes that there are 52% of Negro-Oceanic features, 37% Mongoloid (especially in the Hova), 9% of European (also in the Imerina) and the 2% African-Negro type appears *accidentally* (our italics). There appears to be some stigma about the possibility of an African origin of the population in all the French and Malagasy writers' articles, and in most of these the African-Negroid characteristics are either minimized or described as "accidental," and, without any anthropological basis, negroid affinities are associated with Melanesians or Oceanic negroes. This appears all the more peculiar in the light of the proximity of the island to Africa, of the trade links and of the extensive slave trade with Africa. What the physical assessments and observations here *do* show is that all negroid affinities observed in the tribes are exactly what may have been found in a Bantu-speaking African population.

Although the Merina and Andriana appear to be mainly of Malayo-Indonesian origin there can be no doubt of a fairly strong degree of Negroid admixture. The latter appears to predominate among the Sakalava and the southern tribes. It appears that the central, eastern and northern tribes have a basic Malayo-Indonesian background on to which has been

added varying combinations of Caucasoid (Arabic) and African negro genes. These conclusions are in conformity with the hemoglobin and sickling frequencies.

It is not within the scope of this paper to discuss the definitions of "Mongoloid," "Negroid" and "Caucasoid." Nor is it possible to forecast the results of blending of the genes of each seeing that it is not known how the genes cooperate to produce each of these racial groups in the first place (Boyd, '52). However, it is obvious that:

1. Out of more than 600 Malagasy examined, only two possessed epicanthic folds and true slit-like upward-slanting eyes. Out of 108 Comorians, three possessed these features. If one conjectures that the ancestors of the population were "true" Mongols, these characteristics have been almost "lost." In the Cape Colored population of South Africa (which is essentially a "hybrid" population based on admixtures between Malaysians, Hottentots, and Europeans) epicanthic folds have been rarely observed.

The majority of the Malagasy examined have an "eastern-type" eye which is difficult to define, but which is an eye not usually seen in Europeans and which seems to be produced by somewhat elevated malar bones and a "smooth" upper eyelid.

2. The majority of subjects examined had crinkly, but not pepper-corn, hair.

3. The majority had flattened bridges associated with flattened wide noses whose alae were dilated.

4. There seems to be an even distribution of light and dark skins in the population with emphasis of the one or the other in certain tribes. This is genetically expected in uneven mixtures between Mongoloids and Negroids.

5. The majority seem to exhibit varying degrees of prognathism.

It is considered that the analysis of these observations can go no further than a statement of these facts. Far more detailed studies should be embarked on to determine possible gene frequencies in this rather isolated melting pot of (essentially) three racial groups. Excavations to establish the validity of the tradition of ancestral Vazimba, Teroandroka, Zanakanony and other dwarfs are essential. This more so

since many families and tribes have buried their dead in layers in family tombs over many generations.

## 2. Sickling and serology

It is clear from these results (table 4) that the hemoglobin *S* does occur in Madagascar, and that it has its greatest incidence (about 10%) in tribes such as the Sakalava and Bara who are closest to the Bantu in appearance. In the Merina, outwardly the least African of the tribes, its incidence is lower but still appreciable (3%). We have seen that the sickle-cell in Africa is probably a relatively recent introduction, since tribes south of the Zambezi River show a very low incidence; and it seems possible that the high incidence of sickling in Malagasy tribes such as the Bara and Sakalava may be a reflection of recent Bantu ancestry just as their physical appearance is. We must also remember that the distribution of sickling in Africa is still very patchy, and was formerly without doubt more so: so that Bantu taken to Madagascar would not all have been drawn from tribes of high sickling incidence. There is probably thus far more Bantu blood in the Malagasy than the sickle-cell findings suggest.

It is necessary to deal here with the subject of malaria and sickle-cell distribution. Allison ('54) has shown that the possession of sickle-cell hemoglobin confers some degree of protection against *falciparum* malaria, and it might be argued that the incidence of sickling found in Madagascar is high because the country is — or was until recently — highly malarious. While it is probably true that the sickle-cell will flourish only in a malarious region, this alone cannot explain the findings in Africa (Brain, '55b; Budtz-Olsen and Burgers, '55) or in Madagascar. In particular we see a sharp drop in sickling incidence in the region south of the Zambezi River where malaria is still prevalent. It seems likely that the Zambezi River marks the southern boundary of the spread of the sickling gene in Africa. In parts to the south of the

river however malarious, the sickle-cell does not occur to an appreciable degree because the migration that brought it never reached them (Brain, '53; '55b). In Madagascar too, the diversity in sickling incidence between tribes living in equally malarious areas, suggests that factors other than malaria are operating.

It might be argued, however, that the Negroid element in Madagascar is of Oceanic origin, and that the sickle-cell arrived independently of the Bantu, say by sea from South Arabia. Thus other evidence for African contributions to the Malagasy must be sought. This is provided by the *Rh* blood groups. It is fortunate that we have in the *cDe* chromosome a marker of African origin. All negroid Africans south of the Sahara have this chromosome with an incidence of over 50%, a figure which is not remotely approached by any known non-African-negroid population. The *CDe* chromosome likewise, though less exclusive, is the characteristic *Rh* chromosome of the modern Indonesians who have an incidence of about 80%. Another informative chromosome is *cde* which is absent in the Indonesians and present to a frequency of about 20% in the modern Bantu. We may tabulate the frequencies of these chromosomes in the Malagasy, modern South African Bantu (Shapiro, '51) and modern Javanese (Simmons and Graydon, '47) as follows:

TABLE 7  
*Rh* chromosome frequencies

TRIBE	cDe %	CDe %	cde %
Bantu	65	6	15
Malagasy	43	32	15
Javanese	7	84	0

The findings for the Malagasy are very approximate, but this table shows clearly, firstly that there is African blood in the Malagasy, and secondly, that the African element, genetically speaking, predominates over the Indonesian. One can estimate this predominance by a formula quoted by

Glass and Li ('53). The formula for the percentage make-up of hybrid population in respect to a particular allele is,  $\frac{qx}{q} = \frac{Q}{Q+q} \times 100$  when  $Q$  and  $q$  are the frequencies of the allele in the base populations and  $qx$  in the hybrid population. If we take the modern Bantu and Javanese as representative of the base population — this is probably approximately correct — we find that with respect to the *cDe* chromosome the Malagasy are 62% Bantu and 38% Indonesian, and for the *CDe* chromosome 67% Bantu and 33% Javanese. These figures suggest that the Malagasy are genetically about two parts Bantu to one Indonesian; more exact estimation is certainly unjustified; but the claim that the Malagasy are more African than Indonesian is, we think, conclusively supported.

The absence of abnormal hemoglobins other than *S* in this survey is another fact that needs comment. Of the possible hemoglobins, *C* is a West African variation not yet found in the Bantu and its absence is thus not unexpected. The lack of hemoglobin *E* is more surprising. *E* is a variant which is fairly common in the modern Indonesians (Eng, '55) and so might be expected in Madagascar. However, as shown, the Indonesian element though present is not the dominant one in Madagascar, and hemoglobin *E* might well come to light in a more extensive survey. Such a survey would be exceedingly laborious, but nevertheless well worthwhile. If *E* is not found in Madagascar we would have to consider whether it is not perhaps a recent arrival in Indonesia (after the departure of the Madagascar colonists) just as hemoglobin *S* is in Africa. But this is pure conjecture.

The survey is small and statistically unsatisfactory, but it still provides a fine illustration of the value of single gene characteristics like hemoglobins and blood groups in ethnology.

#### CONCLUSIONS

In a survey of the population of Madagascar the incidence of hemoglobin *S* (sickle-cell) was found to be 4.9%. This



incidence is lower than that found in Central and Southern Africa north of the Zambezi River, but much higher than the percentage south of the river. Taken together with the high frequency of 43% of the "African" *Rh* chromosome *cDe* (*R<sub>o</sub>*), which was demonstrated in a smaller group of the population, it is suggested that the gene for hemoglobin *S* was brought to Madagascar from Africa and not directly from India or other parts of the East, which was a possibility. The findings are compatible with the theory that the sickle gene was introduced into Africa in comparatively recent times, perhaps about the 7th century A.D., by people accompanied by the shorthorn Zebu cattle. For some unknown reason these people did not penetrate south of the Zambezi River, but their descendants, together with cattle, were taken in great numbers as slaves to Madagascar.

The survey indicates that the Malagasy are composed of about two-thirds African and only one-third Indonesian elements. This conclusion cuts right across previous speculations which, based mainly on "physical anthropology," virtually excluded Africans from the origin of the Malagasy; the obvious negroid features were explained by including mythical autochthonous aboriginals and Oceanic negroes in the Indonesian ancestry.

#### ACKNOWLEDGMENTS

The survey on Madagascar was made possible by generous grants from the Dr. C. L. Herman Research Fund, University of Cape Town (to O. B-O, R.S., and P.B.) and the Wenner-Gren Foundation for Anthropological Research, New York (to R.S.).

In Madagascar, Budtz-Olsen and Singer received advice and assistance from Drs. J. Millot and R. Paulian, Director and Assistant Director, respectively, of the Institut de Recherche Scientifique in Tananarive, to whom we feel very indebted. We are also extremely grateful to Général Gourvil, Director of Health and Medical Services, for his gracious

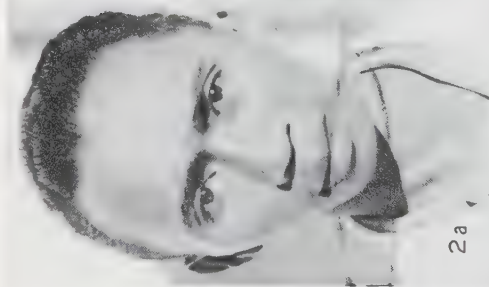
kindness in placing a vehicle at our disposal and arranging our trip to Majunga, where Colonel Orsini helped us considerably. We also appreciate the kindness of Commandant Peyrot of the Madagascar Guard, and of Dr. Touzin of the Hôpital de Befelatanana. We are very appreciative of the continuous assistance of Mlle. la Sère, chief laboratory assistant to Dr. Saugrain, and her Malagasy assistant Augustina.

Dr. J. Zoutendyk, South African Institute for Medical Research, kindly performed the blood grouping, and Miss Girardin, University of Cape Town assisted with the statistical analyses of the physical features. We thank Dr. A. E. Maurant, London, for his helpful criticisms.

#### LITERATURE CITED

- ALLISON, A. C. 1954 Protection afforded by the sickle-cell trait against subtertian malarial infection. *Brit. Med. J.*, 1: 290.
- BELLOY, R. 1909 Quoted by Ratsimamanga (1940).
- BISSCHOP, J. H. R. 1937 Parent stock and derived types of African cattle, with particular references to the importance of conformational characteristics in the study of their origin. *So. Afr. J. Sci.*, 33: 852-870.
- BOYD, W. C. 1952 *Genetics and the Races of Man*. Little, Brown and Co., Boston.
- BRAIN, P. 1953 The sickle-cell trait: A possible mode of introduction into Africa. *Man*, 233.
- 1955a Problems of sickle-cell distribution in Africa. Fifth International Congress of Blood Transfusion: Reports and Communications, p. 436.
- 1955b Incidence of Haemoglobin C in the "Coloured" population of Cape Town. *Nature*, 175: 262.
- BUDTZ-OLSEN, O. E., AND C. J. BURGERS 1955 The sickle-cell trait in South African Bantu. *So. Afr. Med. J.*, 29: 109.
- CURSON, H. H., AND W. R. THORNTON 1936 A contribution to the study of African Native Cattle. *Onderstepoort Journal*, 7: 613.
- DALAND, G. A., AND W. B. CASTLE 1948 A simple and rapid method for demonstrating sickling of the red blood cells: The use of reducing agents. *J. Lab. Clin. Med.*, 33: 1082-1088.
- DART, R. A. 1951 African serological patterns and human migration. *So. Afr. Archaeological Society*, Cape Town.
- DAVID, R. 1940 Le problème anthropobiologie Malgache. *Bull. Acad. Malgache*, 23: 1-31.
- DUBOIS, R. P. H. M. 1926 Les origines des Malgaches. *Anthropos*, 21: 72-126, and 22: 80-124.

- DU TOIT, A. L. 1937 *Our Wandering Continents*. Oliver and Boyd, London.
- ENG, L. L. 1955 Haemoglobin E in Indonesia. *Nature*, 176: 469.
- FAUBLEE, J. 1946 *L'ethnographie de Madagascar*. Bibliothèque d'Outre Mer. Paris.
- GLASS, B., AND C. C. LI 1953 The Dynamics of Racial Intermixture — An Analysis based on the American Negro. *Am. J. Human Genetics*, 5: 1.
- GRANDIDIER, A., AND G. GRANDIDIER 1908 *Ethnographie de Madagascar*. Imprimerie Nationale, Paris.
- GREGORY, J. W. 1921 Quoted by du Toit (1937).
- HORNELL, J. 1934 Indonesian influence on East African Culture. *J. Roy. Anthropol. Inst.*, 64: 305-332.
- JACOBS, M., AND B. J. STERN 1950 *An Outline of General Anthropology*. Barnes and Noble, Inc., New York.
- JOLEAUD, L. 1924 Le beouf de Madagascar. Son origine, son rôle dans les coutumes Sakalaves. *L'Anthropologie*, 34: 103-107.
- LEHMANN, H. 1953 The sickle-cell trait: Not an essentially negroid feature. *Man*, 5.
- 1954 Distribution of the sickle-cell gene. A new light on the origins of the East Africans. *Eugen. Rev.*, 46: (no. 2), 3-23.
- LEHMANN, H., AND M. CUTBUSH 1952 Sickle-cell trait in Southern India. *Brit. Med. J.*, 1: 404-405.
- LINTON, R. 1933 The Tanala. A Hill Tribe of Madagascar. *Field Mus. Nat. Hist. Publ.* 317. Anthropological Series, 22.
- 1943 Cultural sequences in Madagascar. In *Studies in the Anthropology of Oceania and Asia: Papers of the Peabody Museum*, Harvard University, 20: 72-80.
- NAGNORT 1550 Quoted by Sibree, J. (1880).
- NEEL, J. V. 1951 The inheritance of the sickling phenomenon with particular reference to sickle-cell disease. *Blood*, 6: 389-412.
- RAPER, A. B. 1950 Sickle-cell disease in Africa and America. — A Comparison. *J. Trop. Med. Hyg.*, 53: 49-53.
- RATSIMAMANGA, A. R. 1940 Tache pigmentaire hereditaire et origines des Malgaches. *Revue anthropologique*, 50: 5-128.
- RUSILLON 1918 Quoted by Ratsimamanga (1940).
- SCLATER, P. L. 1864 Quoted by Sibree, J. (1880).
- SHAPIRO, M. S. 1951 Further evidence of homogeneity of blood group distribution in the South African Bantu. *So. Afr. Med. J.*, 25: 406-411.
- SIMMONS, R. T., J. J. GRAYDON, B. A. CRONK, G. BARNES AND C. LUMKEMAN 1947 Blood group frequencies in Admiralty Islanders: Further observations on the Fijians and Indonesians and the Rh gene frequencies in some other races. *Med. J. Austr.*, 1: 577.
- SIMMONS, R. T., J. J. GRAYDON, W. M. SEMPLE AND C. N. D. TAYLOR 1951 Blood, Taste and Secretion. *Med. J. Austr.*, 1: 425.
- SINGER, E. 1953 The sickle-cell trait in Africa. *Amer. Anthropologist*, 55 (no. 5, pt. 1): 634-648.



2a



3a



4a



5a



6a



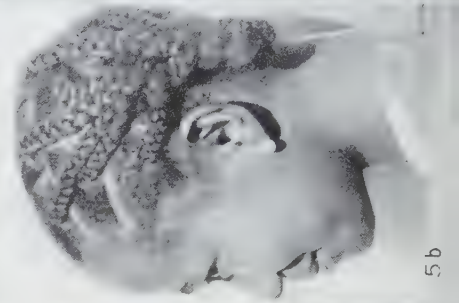
2b



3b



4b



5b



6b

# PRECONDYLAR TUBERCLES IN AMERICAN WHITES AND NEGROES

GEORGE E. BROMAN, JR.

*Department of Anatomy, Washington University School of Medicine,  
St. Louis, Missouri*

SIX FIGURES

It is the purpose of this paper to determine the types and incidences of precondylar tubercles in crania of American Whites and Negroes, and to evaluate the various theories which have been proposed to explain their formation.

Interest in this problem was aroused by the recent paper by Marshall ('55) in which he reported the incidences of precondylar tubercles in series of Oceanic crania. He compared his figures with those for European crania (Cited by Le Double, '03 from a report by Legge, 1885) and for crania of the North Pacific coast (Oetteking, '30), and called attention to the "contradicting explanatory theories" which have been offered.

Le Double ('03, p. 94) described the tubercles as follows: "Several millimeters in front of the anterior margin of the foramen magnum or on this margin, most often on both sides of the median line, separated by a cleft of variable size, and sometimes continuous with the occipital condyles, one may find bony growths, of variable shape and mass, symmetrical or asymmetrical, which Kalenscher (1893) called accessory eminences".<sup>1</sup> Thus, Le Double noted variations in the relationship of tubercles to the occipital condyle.

In his survey of the crania of the North Pacific coast, Oetteking included with precondylar tubercles all forms of "the manifestation of occipital vertebra," such as condylus

<sup>1</sup> Author's translation.



tertius, labia foraminis magni, bipartition of canalis hypoglossi, canalis intrabasilaris, incisura marginalis posterior, processus basillares and paracondyloidei, etc.

While Marshall did not define his concept of what constitutes precondylar tubercles, he presented the photograph of a cranium with tubercles which are continuous with the occipital condyle. After communication ('56) with Marshall, he re-examined the Harvard series of Hawaiian crania and verified this interpretation for all but one which presented a unilateral tubercle not continuous with the condyle. His other Polynesian series, as well as the Melanesian and Micronesian series, were not easily available for re-examination.

Hence, a review of the literature shows that there may be more than one type of tubercle called precondylar, and that all types have not been included by each author.

Various theories to explain the formation of these tubercles have been advanced. Kollman ('05) considered them to be one manifestation of an occipital vertebra. Bolk ('21), on the other hand, described the variation as evidence of the positive developmental potential ("positive Entwicklungskraft") of the medial ends of occipital condyles. He assumed that normally the condyles migrate laterally during development, but that in some cases, the medial ends remain stationary and become tubercles which may fuse. When separate, they were designated by Bolk as "Tubercula basilaria" and when fused, as a third condyle.

In addition to these concepts based on the assumption that precondylar tubercles are formed during the development of the occipital bone is the explanation by Charles (1893) suggesting that they may develop during adult life. According to Charles (1893), "The third condyle . . . may either be an articular depression, a single and medium tuberosity with an articular facet, a bilateral facettted tuberosity or, lastly, a unilateral or bilateral non-articular tubercle. It may articulate with either the anterior arch of the atlas, medially or laterally, or with the odontoid process. It may be developed in the suspensory ligament, in the median occipito-atloid liga-

ment, or in the anterior lateral occipito-atloid ligament." It is inferred from this that Charles attributed the tubercles to ossification within these ligaments during adult life.

Also, there is the suggestion of Oetteking ('30) and of Marshall ('55) that artificial deformation of the cranium may cause and/or influence the size of precondylar tubercles.

It may be seen, therefore, that the literature contains disagreement concerning the mode of formation of the precondylar tubercle, as well as its complete definition.

#### MATERIAL AND METHOD

The Terry Collection of skeletons is ideal for this purpose because of its size, documentation, and the availability of cervical vertebrae matching each cranium. The number of crania examined is shown in table 1 according to race, sex and age.

The crania of this series present precondylar tubercles of two types: (1) a discrete structure, and (2) a structure continuous with the occipital condyle. In addition, differences in configuration are seen between the two types. Those tubercles which are discrete structures and not continuous with the occipital condyle are rough and irregular in contour and are classified as Type I (figs. 1, 3, 5); those which are continuous with the occipital condyle are regular and well-rounded in contour and are classified as Type II (figs. 2, 4, 6).

It was noted whether the tubercles were unilateral (right or left) or bilateral. The relation between tubercle and occipital condyle was determined and the length of the tubercle in millimeters was measured as the perpendicular extent of its projection from the midline surface of bone directly medial. Various stages of midline fusion of bilateral tubercles were seen (figs. 5 and 6); when fusion was complete (fig. 6), the variation was listed as one left tubercle and one right tubercle of equal length, measured as the perpendicular extent from the midline surface of bone directly anterior.

Whether or not a tubercle had been articulated in the recent state with either the anterior arch of the atlas or with the dens

TABLE 1  
*Distribution of types of precondylar tubercle according to race, sex and age*

AGE	WHITE			NEGRO			TOTAL
	Male	Female	No. of crania with tubercles	Male	Female	No. of crania with tubercles	
	No. of crania	No. of crania		No. of crania	No. of crania		
	tubercles	tubercles		tubercles	tubercles		
<i>years</i>							
<i>Type I</i>							
14-20	3	0	0	0	9	22	0
21-30	7	1	4	2	46	140	5
31-40	27	0	7	1	65	212	3
41-50	77	2	17	2	59	260	5
51-60	112	1	34	3	45	299	5
61-70	123	1	54	2	49	298	7
71-80	80	3	47	3	35	192	8
81-90	14	0	33	1	12	68	1
91-100	0	0	2	1	6	9	1
101-102	0	0	0	0	1	1	0
♀	1	0	10	3	12	26	1
Total	444	8 (1.8%)	208	536	12 (2.2%)	339	36 (2.4%)
<i>Type II</i>							
14-20	3	0	0	0	9	22	1
21-30	7	0	4	5	46	140	10
31-40	27	4	7	2	65	212	10
41-50	77	6	17	6	59	260	19
51-60	112	10	34	6	45	299	23
61-70	123	9	54	6	49	298	28
71-80	80	7	47	3	35	192	13
81-90	14	1	33	9	12	68	11
91-100	0	0	2	1	6	9	0
101-102	0	0	0	0	1	1	0
♀	1	0	10	3	12	26	3
Total	444	37 (8.3%)	208	536	26 (4.9%)	339	118 (7.7%)

of the axis was difficult to assess. In a few instances, the contour of the tubercle suggested the presence of an articular facet (fig. 5) or a surface which had been covered with cartilage (fig. 3). However, in each case the decision was based on contact determined by articulation of the cranium with the atlas and axis.

TABLE 2

*Distribution of tubercles according to type, race, sex, size and side of the body*

SIZE	MALE		FEMALE		TOTAL
	Right	Left	Right	Left	
<i>mm</i>					
<i>Type I</i>					
White					
Trace-1.4	5	4	2	2	13
1.5-2.9	0	3	1	2	6
3.0-4.4	0	1	3	1	5
4.5-	0	0	0	1	1
Total	5	8	6	6	25
Negro					
Trace-1.4	2	5	3	2	12
1.5-2.9	1	4	4	2	11
3.0-4.4	1	0	0	0	1
4.5-	2	3	0	0	5
Total	6	12	7	4	29
<i>TYPE II</i>					
White					
Trace-1.4	20	23	10	13	66
1.5-2.9	9	9	1	2	21
3.0-4.4	3	3	4	6	16
4.5-	0	0	0	3	3
Total	32	35	15	24	106
Negro					
Trace-1.4	15	15	16	16	62
1.5-2.9	5	6	4	8	23
3.0-4.4	0	3	3	3	9
4.5	0	0	0	1	1
Total	20	24	23	28	95

## OBSERVATIONS

Table 1 shows the incidence of the two types of precondylar tubercles according to race, sex and age. It may be seen that there is no significant increase with increase in age. There are no significant differences between male and female or between White and Negro in tubercles of Type I. However, tubercles of Type II occur more frequently in females than in males, and more frequently in Whites than in Negroes. Both of these differences are significant at the .05 level (Chi square test).

The distribution of precondylar tubercles according to type, race, sex, size and side of the body is shown in table 2. The 54 tubercles of Type I (25 in White and 29 in Negro crania) represent 18 unilateral examples, 6 on the left and 12 on the right, and 18 bilateral examples. In the pairs, the right member was the larger in 4 cases and the left member in 4 cases, leaving 10 in which the two tubercles were equal in size. The 201 tubercles of Type II (106 in White and 95 in Negro crania) representing 35 single tubercles and 83 pairs, show essentially the same picture; there were 7 single tubercles on the right and 28 on the left; the right member was larger in 11 pairs, the left in 10 pairs, and the two were equal in size in 62 pairs.

The majority of tubercles for each sex and race were less than 3 mm long. No significant variation in size distribution is seen for either race or sex.

Articulation was determined to have been probable in 10 of 36 cases (27%) of Type I tubercles and in 36 of 108 cases (31%) of Type II tubercles.

## DISCUSSION

Le Double ('03) referred to a study by Legge (1885, not available) in which two cases of "eminences accessoires," one unilateral and one bilateral, were found in a series of 780 unsexed crania, probably European. In the North Pacific



Coast series, Oetteking ('30) found an incidence of "manifestation of occipital vertebra" of 14.8% in crania not artificially deformed and an incidence range of 4.3% to 28.0% among groups of crania showing artificial deformation. These figures will not be compared with the data derived from the Terry Collection, Legge's for lack of information and Oetteking's because of the inclusion of other variations.

Of interest, however, is the comparison with data presented by Marshall. Including all but one of the various Oceanic island groups, the incidences range from 13.4% to 20.7%. The exception is the group of only 21 Fiji crania with an incidence of 4.8%. These figures, with the exception noted, are all higher than the combined incidences of Types I and II in the Terry Collection (10.1%). Most pertinent is the incidence in the Harvard Hawaiian series (13.4%). This value is directly comparable as these tubercles (except in 1 case) have been established to be Type II and the incidence is almost twice that of Type II in the Terry Collection (7.7%).

The possible significance of artificial deformation in the development of precondylar tubercles varies according to the theory of formation under consideration. The significance is concluded to be negligible in considering Kollman's theory that the tubercles are a manifestation of an occipital vertebra, since vestiges of an occipital vertebra would be present long before artificial deformation could be attempted. However, the influence of artificial deformation becomes a possibility if the explanatory theories of Bolk and Charles can be substantiated. Each of these theories ("positive Entwicklungskraft" and ossification of ligaments) involves a process which may be active during the period when deformation is practiced.

The finding of two distinct types of precondylar tubercles is not compatible with any one explanatory theory of formation. Thus, more than one type of tubercle provides evidence to support more than one theory of formation and, conversely, the different theories of formation lend support to

the distinction of more than one type of tubercle. It may be seen in table 1 that the ranges of incidence of Type I (1.8%–3.8%) according to race and sex do not overlap the ranges for Type II (4.9%–11.5%). While the separation is not great, its consistency among the four groups is suggestive. In addition, there is evident in Type II a greater tendency toward a bilateral condition than in Type I. If tubercles of Type II are to be attributed to either of the developmental factors of causation (manifestation of occipital vertebra or “positive *Entwicklungskraft*”), it would be expected that the more common situation would be that of bilateral tubercles, which is the case. Also, it might be expected that the process of ossification within a ligament would have no predictable tendency for either unilateral or bilateral distribution, which is the case in Type I. It is interesting to postulate that tubercles of Type I appear during adult life, since they show no predilection for either race or sex; and, that tubercles of Type II are inherent variations manifested in the very early development of the occipital bone, since their incidence is significantly different for both sex and race among the American White and Negro series.

While the distinction of types made in this study was based upon observation, the correlative analysis of the types and the theories of formation may serve to resolve the conflict of ideas in the literature. Indeed this analysis provides support of several theories which are incompatible when applied to the precondylar tubercle as a single entity. Hence one may agree with Charles that tubercles of Type I are the result of ossification within a ligament during adult life, while supporting, also, either “positive *Entwicklungskraft*” or “manifestation of occipital vertebra” as the basis of formation of tubercles of Type II.

A study of tubercles is needed on crania before maceration and at various stages of development and maturity in order to determine what conditions produce them.

## SUMMARY AND CONCLUSIONS

Two types of precondylar tubercles have been described: Type I as a discrete entity, and Type II continuous with the occipital condyle. The incidence of each type in the Terry Collection has been determined, and the data have been examined for significant differences according to race and sex. Some correlation with different theories of the formation of precondylar tubercles has been suggested.

It is found that there is no increase in incidence with increase in age. Race and sex differences are not present among tubercles of Type I, while tubercles of Type II occur more frequently in females than in males and more frequently in Whites than in Negroes. Type II shows a greater frequency of the bilateral condition than does Type I.

It is suggested that the theories of formation (of the tubercles) are not mutually exclusive, as Type I tubercles might be attributed to ossification within a ligament and Type II to either a "positive Entwicklungskraft" or "manifestation of occipital vertebra."

## LITERATURE CITED

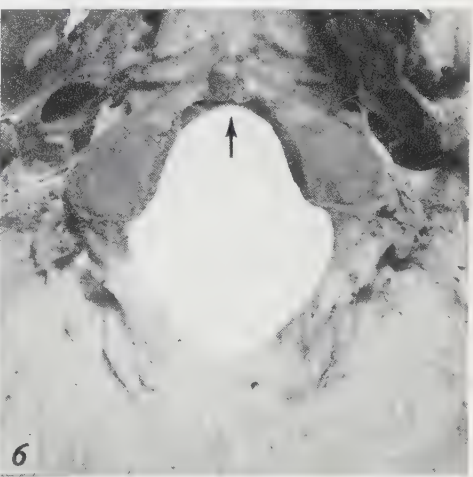
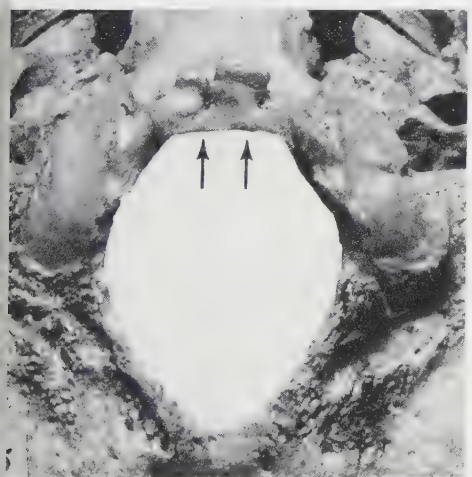
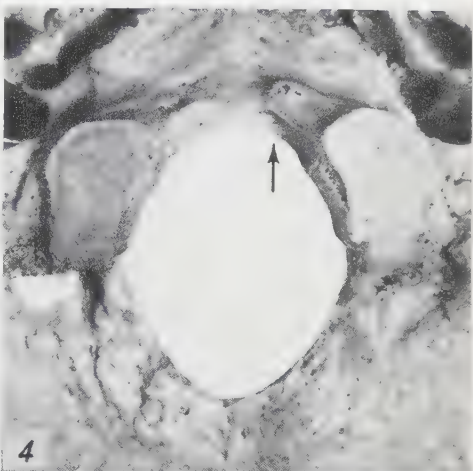
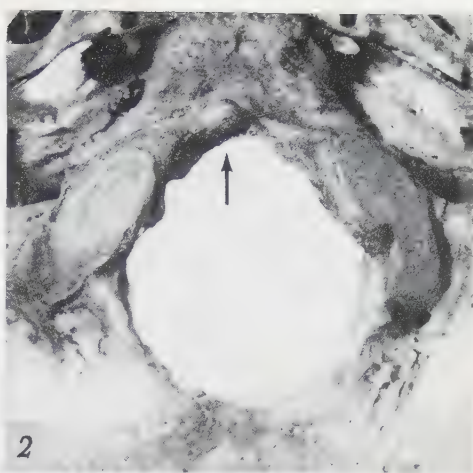
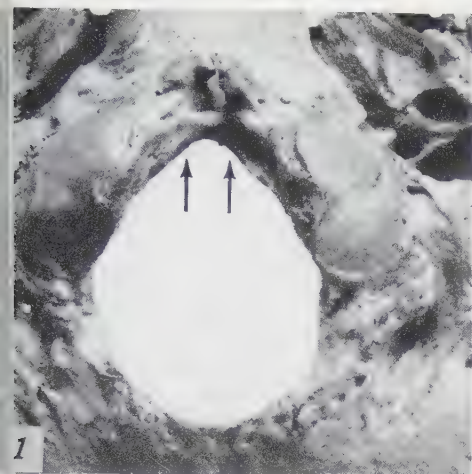
- BOLK, L. 1921 Die verschiedenen Formen des condylus tertius und ihre Entstehungsursache. *Anat. Anz.*, vol. LIV.
- CHARLES, R. H. 1893 Contributions to the craniology and craniometry of the Punjab tribes. *J. Anat. Physiol.*, vol. XXVII.
- KOLLMAN, F. 1905 Varianten am os occipitale, besonders in der Umgebung des Foramen occipitale magnum. *Anat. Anz.*, vol. XXVII.
- LE DOUBLE, A. F. 1903 *Traité des variations des os du crâne de l'Homme*. Paris.
- MARSHALL, D. S. 1955 Precondylar tubercle incidence rates. *Am. J. Phys. Anthropol.*, vol. XIII (1).
- 1956 Personal communication.
- OETTEKING, B. 1930 Craniology of the North Pacific Coast. *Memoirs of the American Museum of Natural History*, vol. XV.

## PLATE 1

### EXPLANATION OF FIGURES

Examples of precondylar tubercles ( $\times 1$ ) of two types.

- 1 No. 682R, Negro male, 73 years. Bilateral tubercles of Type I. The right tubercle is 9.5 mm long and the left is 10.0 mm long. Note the independence from occipital condyles at the medial inclination of each, although no fusion has occurred.
- 2 No. 415, White male, 47 years. Right tubercle of Type II, 3.5 mm. Note continuity with occipital condyle.
- 3 No. 491R, White female, 65 years. Bilateral tubercles of Type I, each 4.0 mm long. The inferior surfaces of the medial ends are flattened and probably were covered with cartilage in the recent state.
- 4 No. 1253, Negro male, 59 years. Left tubercle of Type II, 3.0 mm (inferior surface of medial end slightly damaged).
- 5 No. 1517, White female, 76 years. Bilateral tubercles of Type I; right, 3.5 mm and left, 4.5 mm. Note partial fusion, and articular facet on left.
- 6 No. 1340R, Negro male, 58 years. Bilateral tubercles of Type II showing complete fusion, 5 mm long. Note suggestion of a vertebral outline around foramen magnum.







# A STUDY OF THE FORMATION OF THE SURAL NERVE IN ADULT MAN

DONALD F. HUELKE

*Department of Anatomy, University of Michigan Medical School,  
Ann Arbor, Michigan*

FIVE FIGURES

## INTRODUCTION

According to textbooks of anatomy the sural nerve is either a direct continuation of the medial sural cutaneous branch of the tibial nerve or is formed by the union of this nerve with the peroneal communicating branch of the lateral sural cutaneous nerve (a branch of the common peroneal nerve). This union may take place anywhere between the popliteal fossa and the lateral malleolus.

Information on the site and type of formation of the sural nerve in various nationalities has been gathered by Bardeen ('06), Gluschkow ('18), Catania ('24), Kosinski ('25), Andreassi ('31), Ssokolow ('33), Mogi ('38), P'an ('39) and Williams ('54). In the majority of these studies the cadaver material was known to be of one nationality. In general, however, the nationality and the degree of racial mixture of the cadaver material in the United States is unknown to the anatomist.

## MATERIALS AND METHODS

The material of this study consisted of 352 lower limbs of which approximately 70% were dissected by the author. The remainder were checked and recorded by the author from routine classroom dissections. One hundred eighty-one (51.4%) right side and 171 (48.6%) left side dissections

were recorded. Separation according to race and sex was not made.

The data here presented were obtained by examination of material in the Anatomy Department of the University of Illinois School of Medicine; Loyola University School of Medicine; The Chicago Medical School; The University of Chicago School of Medicine; University of Michigan Medical School; and the University of Illinois, Department of Physiology, Urbana, Illinois.

To determine the cutaneous pattern of the posterior aspect of the leg, the tibial and common peroneal nerves were isolated in the popliteal fossa. Each nerve was then dissected to expose the origin of the medial sural cutaneous, the lateral sural cutaneous, and the peroneal communicating branches. These nerves were then traced to their termination. The manner in which the sural nerve was formed was recorded, and, if the pattern of the formation proved unusual, a sketch was made (figs. 2, 3, 4, 5).

#### OBSERVATIONS AND RESULTS

Three types of sural nerves, designated A, B, and C may be described (after P'an, '39). In type A, the sural nerve is formed by the union of the medial sural cutaneous branch of the tibial nerve and the peroneal communicating branch of the common peroneal nerve. Occasionally the peroneal communicating branch joins the medial sural cutaneous nerve by more than one branch (figs. 4 and 5). The union of these two nerves occurs in the lower half of the leg. In type B, the sural nerve is the continuation of the medial sural cutaneous nerve and the peroneal communicating branch is absent. The type C sural nerve is formed by the peroneal communicating branch only. This type is rare; in only one specimen was the medial sural cutaneous nerve completely absent (fig. 1).

The frequency of occurrence of the three types of sural nerves is presented in table 1. Of the 352 lower extremities, 284 or 80.7% belong to type A; 67 limbs (19.0%), to type B;

and only one limb (0.3%), to type C. The A and B types appear with the same frequency whether in the right or the left limb.

Previous investigations of the formation of the sural nerve in American cadavers have shown conflicting results (table 2). The data of Williams agree closely with those of this study,

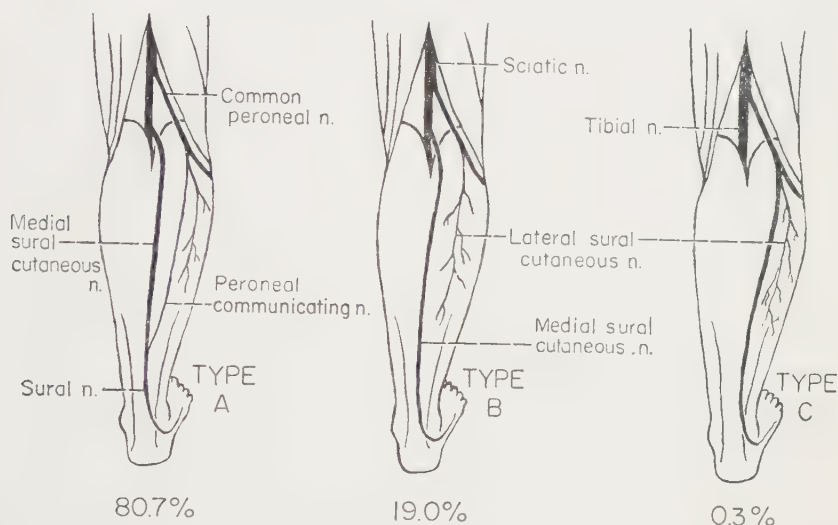


Fig. 1 The manner of formation of the sural nerve. A type A sural nerve is formed by both components. A type B nerve is a continuation of the medial sural cutaneous nerve. Type C is the rare type of formation in which only the peroneal communicating branch extends to the foot as the sural nerve.

TABLE 1

*The distribution of the three types of sural nerves*

TYPE	RIGHT		LEFT		COMBINED	
	Number	%	Number	%	Number	%
A. Anastomotic	146	80.7	138	80.7	284	80.7
B. Tibial non-anastomotic	35	19.3	32	18.7	67	19.0
C. Peroneal non-anastomotic	0	0.0	1	0.6	1	0.3
Total	181	100.0	171	100.0	352	100.0

but Bardeen's data differ considerably. He indicated that the type A formation is found in only 59.2% of cases, while type B occurred in 39.5% of the dissections.

Examination of the distribution of the three types of sural nerves in Chinese, Japanese, Russian, Italian and Polish material show a marked difference between the Oriental and European groups (table 3). Comparison of tables 2 and 3 reveals that American and Oriental groups are quite similar both having approximately the same distribution of the three types of sural nerve. It might be expected that the present findings and those of Williams would approximate those of

TABLE 2  
*Frequency of the three types of sural nerves in American cadavers*

TYPES	HUELKE 1956 352 Cases <sup>1</sup>	WILLIAMS 1954 257 Cases	BARDEEN 1906 76 Cases
	%	%	%
A. Anastomotie	80.7	83.7	59.2
B. Tibial non-anastomotie	19.0	15.9	39.5
C. Peroneal non-anastomotie	0.3	0.4	1.3

<sup>1</sup> In this study, data were taken from 132 limbs which were also used by Williams in his report.

the European series since most of the American cadavers are Caucasian (89.8% in this study; Williams — 83.1%). This is not the case however, for the European groups have a markedly different distribution of the three types of sural nerves (table 3). The non-Caucasian limbs of this study are from Negro cadavers. The findings on these limbs do not alter the percentages presented, for the type A sural nerve is predominant among the Negro cadavers.

In type A the site of union of the medial sural cutaneous nerve and the peroneal communicating branch is extremely variable. This union may take place anywhere between the popliteal fossa and the lateral malleolus. In recording the



TABLE 4  
*Analysis of the site of formation of sural nerves of type A*

	GERMAN (Pan) 1939 286 cases		GERMAN (Mogi) 1938 180 cases		RUSSIAN (Ghushkow <sup>1</sup> ) 1918		RUSSIAN (Skokolow <sup>1</sup> ) 1933 500 cases		ITALIAN (Andreassi) 1931 144 cases		ITALIAN (Catania) 1924 94 cases		POLISH (Kosinski) 1924 234 cases	
	%		%		%		%		%		%		%	
A. Anastomatic	81.5		83.3		38.0		52.6		63.9		51.0		40.2	
B. Tibial non-anastomatic	13.3		16.7		58.0		43.8		34.7		35.0		53.8	
C. Peroneal non-anastomatic	5.2		0.0		4.0		3.6		1.4		14.0		6.0	
<sup>1</sup> Number of cases not stated.														
	AMERICAN (Huelke) 284 cases		CHINESE (P'an) 233 cases		POLISH (Kosinski) 94 cases		JAPANESE (Mogi) 150 cases		RUSSIAN (Skokolow <sup>1</sup> ) 263 cases					
1. Upper quarter of the leg	Right 32 } Left 37 }	69 24.3%	Right 7 } Left 9 }	16 6.9%	9.3%									
2. Second quarter of the leg	Right 25 } Left 23 }	48 16.9%	Right 11 } Left 14 }	25 10.7%										
3. Third quarter of the leg	Right 58 } Left 46 }	104 36.6%	Right 64 } Left 56 }	120 51.5%	65.1%									
4. Fourth quarter of the leg	Right 31 } Left 32 }	63 22.2%	Right 32 } Left 40 }	72 30.9%										
1. Upper one-half and of the leg	Right 57 } Left 60 }	117 41.2%	Right 18 } Left 23 }	41 17.6%	27.9%		33.3%		34.2%					
3. Lower one-half and of the leg	Right 89 } Left 78 }	167 58.8%	Right 96 } Left 96 }	192 82.4%			66.7%		65.8%					
Ratio (1 and 2):(3 and 4)	1:1.4		1:4.7		1:2.6		1:2.0		1:1.9					

<sup>1</sup> The author in this series divided the leg into three regions instead of four. Pan converted the data to conform with the Chinese and Polish series.

<sup>2</sup> No data available for the Italian (Catania and Andreassi), Russian (Ghushkow), or American (Bardene and Williams).

TABLE 5  
*Symmetry and asymmetry in the formation of the sural nerve*<sup>1</sup>

TYPES OF SURAL NERVE	AMERICAN (Huelke <sup>2</sup> ) 150 bodies		CHINESE (P'an) 143 bodies		JAPANESE (Mogi) 90 bodies		RUSSIAN (Sokolow) 250 bodies	
	no.	%	no.	%	%	%	%	%
A. Anastomotic	108	72.0	105	73.4	74.4	42.0		
B. Tibial non-anastomotic	16		12					
C. Peroneal non-anastomotic	0	10.7	3	10.5	7.8	36.8		
Total (A + B + C)	124	82.7	120	83.9	82.2	78.8		
MIXED TYPES:								
Right A; Left B or C	15		9					
Left A; Right B or C	11	17.3	14	16.1	17.8	21.2		
Asymmetrical								

<sup>1</sup> See footnote 2, table 4.

<sup>2</sup> Of the 352 limbs used in this study, 52 were unpaired; therefore only 300 limbs (150 individuals) are presented.

observations, each leg was considered to be divided into 4 parts. The popliteal fossa was designated as region 1. The limb distal to the fossa was divided into three equal parts — the second quarter, the third quarter, and the fourth quarter of the leg. Analysis of the level of formation of the type A sural nerve of this study, along with the data collected by other investigators, is presented in table 4.

The Chinese and Polish series are very much alike in that the sural nerve is formed more frequently in the lower half of the leg than in the upper, and most frequently in the third quarter of the leg. The Japanese and Russian series also show the lower half of the leg as being the more frequent site of union.

The data collected in this study indicate that the third quarter of the leg is the most constant site for the formation of the sural nerve. The ratio between the upper half and the lower half of the legs examined is 1:1.4, whereas in the nationalities mentioned above this ratio is more striking, Chinese 1:4.7; Polish 1:2.6; Japanese 1:2.0; Russian 1:1.9 (table 4).

Observations on symmetry and asymmetry in the formation of the sural nerve in both legs of the same body are presented in table 5. The symmetrical group had the same type of formation in both legs, while the asymmetrical group had the anastomotic type (A) in one leg and a non-anastomotic type (B or C) in the other leg.

In 150 bodies (300 paired lower limbs), 124 nerve patterns were symmetrical and 26 were asymmetrical. Of the 124 symmetrical patterns 108 were the anastomotic type (A); 16 were of the non-anastomotic type (B). The American, Chinese, Japanese and Russian groups had practically the same percentage of symmetrical and asymmetrical distribution. In the symmetrical group the anastomotic type was more frequent in the American (72.0%), Chinese (73.4%) and Japanese (74.4%) than in the Russian (42.0%). Conversely the non-anastomotic type appeared more often (36.8%) in

the Russian group than in the American (10.7%), Chinese (10.5%) or Japanese (7.8%) groups.

Information on the distribution of the cutaneous nerves in anthropoids indicates that the sural nerve is always of the tibial non-anastomotic type (Ssokolow, '33). In man the formation of this nerve is more complex; in 80.7% the sural nerve is formed by two component branches, one from the tibial nerve, the other from the common peroneal nerve. Rarely (0.3%) is it formed only by a branch from the common peroneal nerve. Approximately one instance in five is of the tibial non-anastomotic type, which is the constant type among the anthropoids.

#### SUMMARY

1. The site and formation of the sural nerve were studied in 352 lower limbs of adult cadavers from midwestern United States.

2. The sural nerve was formed by two components; one from the tibial, the other from the common peroneal nerve in 284 limbs (80.7%). Occasionally the sural nerve is a continuation of the tibial portion only (19.0%); very rarely does it consist of a peroneal branch without a tibial component (0.3%).

3. The sural nerve was formed most frequently in the third quarter of the leg (36.6%) and more often in the lower half (58.8%) than in the upper half (41.2%).

4. The majority of cadavers (82.7%) had the same type of sural nerve in both legs.

5. The similarities of the site and formation of the sural nerve in American, Chinese and Japanese bodies, and the differences between these and European groups are noted.

#### ACKNOWLEDGMENT

The author is indebted to Dr. W. P. Elhardt, Department of Physiology, University of Illinois; Drs. R. T. Woodburne,

W. T. Dempster, and T. M. Oelrich, Department of Anatomy, University of Michigan Medical School, for their encouragement, assistance and criticism.

## LITERATURE CITED

- ANDREASSI, G. 1931 Osservazioni intorno all'origine, comportamento e distribuzione dei nervi cutaneo mediale della sura, ramo anastomotico peoniero e cutaneo laterale della sura nell'uomo. *Ricerche di Morfologia*, 11: 83-100.
- BARDEEN, C. R. 1906 Development and variation of the nerves and the musculature of the inferior extremity and of the neighboring regions of the trunk in man. *Am. J. Anat.*, 6: 259-391.
- CATANIA, V. 1924 Il comportamento dei nervi cutanei dorsali del piede. *Arch. ital. de anat. e di embriol.*, 21: 295-331.
- GLUSCHKOW, P. A. 1918 Über die Innervation des Füßrucksens. Kasan (Russia). Taken from Ssokolow, 1933.
- KOSINSKI, C. 1926 The course, mutual relations and distribution of the cutaneous nerves of the metazonal region of the leg and foot. *J. Anat.*, 60: 274-297.
- MOGI, E. 1938 Über die Sensiblen Wandennerven bei den Japanischen Zwillingen. *Okaj. Folia Anat. Jap.*, 16: 229-274.
- P'AN, M. T. 1939 Formation of the sural nerve in the Chinese. *Am. J. Phys. Anthropol.*, 25: 311-321.
- SSOKOLOW, P. 1933 Zur Anatomie des n. suralis beim Menschen und Affen. *Ztschr. f. d. ges. Anat.*, 100: 194-217.
- WILLIAMS, D. D. 1954 A study of the human fibular communicating nerve. *Anat. Rec.*, 120: 533-544.

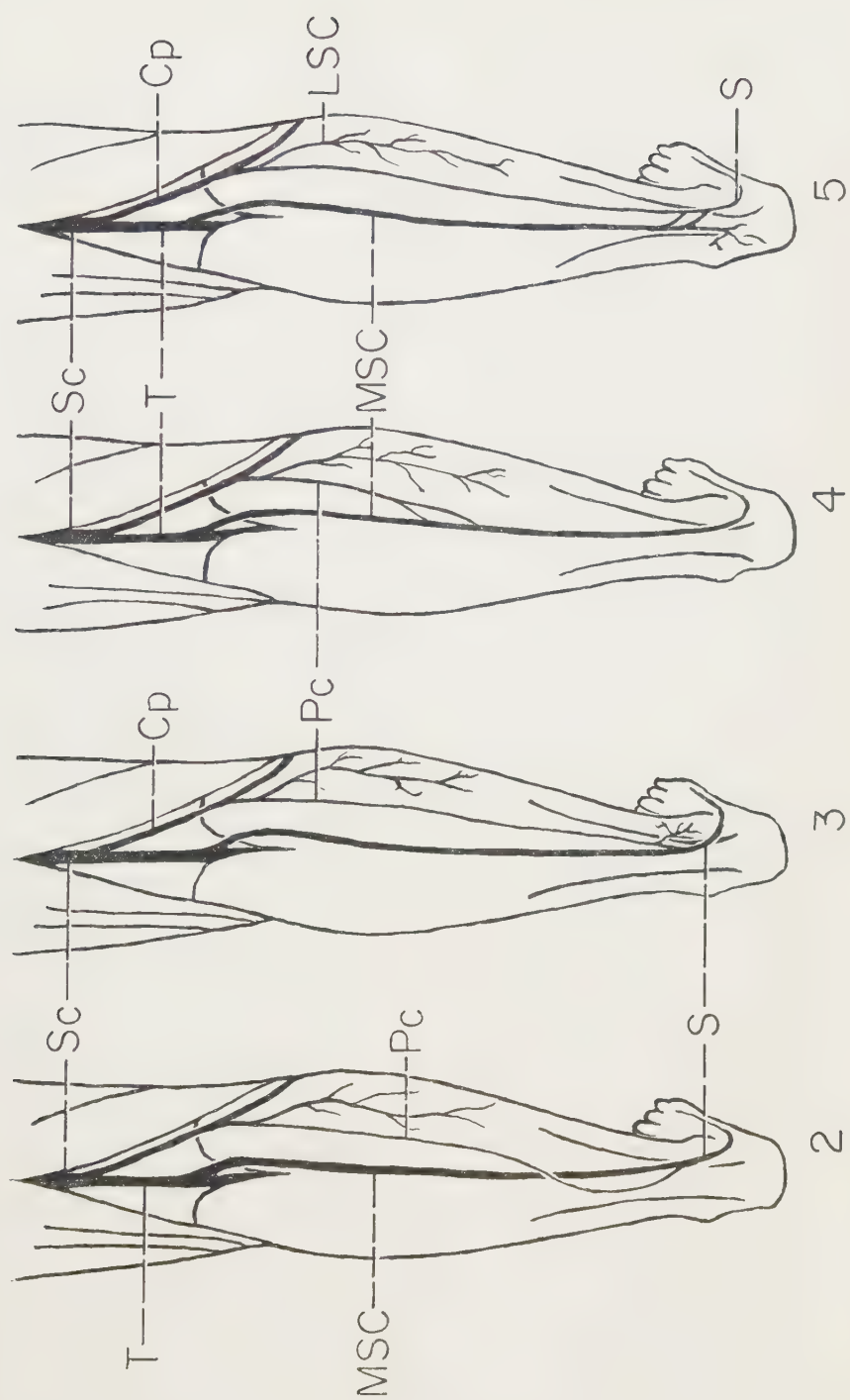


# PLATE 1

## EXPLANATION OF FIGURES

Variations in the formation of sural nerves of type A

- Se — sciatic nerve; T — tibial nerve; Cp — common peroneal nerve; Pe — peroneal communicating branch; MSC — medial sural cutaneous nerve; LSC — lateral sural cutaneous nerve; S — sural nerve.
- 2 The peroneal communicating branch crosses over the medial sural cutaneous nerve to join it on its medial side in the 4th quarter of the leg.
- 3 The peroneal communicating branch gives off a large branch to the skin behind the lateral malleolus just before forming a sural nerve of type A.
- 4 A type A sural nerve formed by two peroneal communicating branches joining the medial sural cutaneous nerve.
- 5 The medial sural cutaneous nerve is shown joining the peroneal communicating branch by two radicles and then ending in a cutaneous termination behind the medial malleolus.





# THE KELL ANTIGEN IN AMERICAN INDIANS

WITH A NOTE ABOUT ANTI-KELL SERA <sup>1</sup>

BRUCE CHOWN AND MARION LEWIS

*Blood Group Reference and Research Laboratory,  
Winnipeg, Canada,<sup>2</sup> and The Department of  
Pediatrics, University of Manitoba*

We have never found a pure-blood Canadian Indian to be Kell-positive (Chown and Lewis, '53, '56 for lit., and unpublished data). When, therefore, Pantin and Junqueira ('52) reported a frequency of 10.17% *K*+ among 423 Brazilian Indians and Matson, Koch and Levine ('54) 10.7% among Chippewa Indians of northern Minnesota we were both interested and disturbed.

It seemed to us that these latter Chippewa Indians should not differ genetically to a significant degree from their neighboring Canadian Indians, although this was possible: Matson and Schrader ('33) had shown the Blackfoot to differ significantly from other Indian tribes in the frequency of the gene *A*. The Chippewa, according to the Rev. Peter Jones, himself a Chippewa (Jones, 1872), were living in south western Ontario around the year 1800, but were said to have come from farther west and to have made war raids as far as the land of the Flatheads in present Idaho. The territory of the Chippewa of northern Minnesota was contiguous to that of the Crees to the north, and it is almost certain that there was intermarriage between these tribes.

<sup>1</sup> Part of a continuing study of the blood groups of the American Indians and Eskimos carried out under the aegis of the National Museum of Canada, Ottawa.

<sup>2</sup> Address 735 Notre Dame Ave.

Among the Crees we have found but a rare *Kell*-positive, and in every such case there has been at least one white ancestor from whom the *Kell* gene might have been derived.

The problem was discussed with Dr. Matson and Dr. Levine and with their active cooperation we undertook to repeat the study. This we did in the winter of 1955-56, paying two visits to the Reserve. On the first, in order to determine the frequency of *K* in the population, we tested 171 random unrelated individuals: no *K*+ was found. Dr. Matson then sent us a list of the 53 *K*+ from the 1954 study, while Dr. Levine provided 5 additional anti-*K* sera, and we paid a second visit with the intent of testing as many of these 53 as we could find. By chance 6 of the 171 in the first sample were members of this group; 33 others were retested on the second visit. Of these 33, 5 were found to be *K*+: all 5 were known to have at least one white ancestor. Dr. Matson subsequently tested one more of the original *K*+ group who had moved to Minneapolis and found her to be *K*—. In brief 35 out of 40 originally found to be *K*+ and now retested were found to be *K*—.

#### SERA AND METHODS

Samples of capillary blood were taken in saline in the morning and tested in the afternoon. In the first part of the study three anti-*K* sera were used: 1 saline-reacting (Mar) in the capillary (Chown and Lewis, '51) and two indirect Coombs (Ram. and R. B.) by our standard indirect Coombs method. In our latter method we incubate two parts of serum with one part of washed, packed cells in a covered serology tube at 37°C. for one hour. We then wash the cells 4 times and remove all the supernatant. For the final stage we take up one part of selected anti-human globulin serum in a capillary followed by one part of the treated cells, invert the tube and set it against a lighted glass slant at an angle of 45°. Reactions and time are recorded, negative readings being made when no agglutination has taken place in 10 minutes.



Cells sensitized with the sera Ram. and R. B. give complete agglutination in one minute or less. A control  $K+$  blood was run each day and gave the expected reactions with all three sera.

In the second part of the study, since the individuals were now selected, i.e.  $K+$  from the original study, 5 indirect Coombs anti- $K$  (P 2394, Mast., Tren., Marn. and Rad.) as provided by Dr. Levine were added to the battery of testing sera, as was a saline-reacting anti- $k$  (Cellano). Each sample was tested with anti- $K$  (Mar) and anti- $k$  in the capillary, with anti- $K$  (Ram) by indirect Coombs and with two of the other anti- $K$  sera in varying combinations by indirect Coombs: for example the first 5 people were tested with P 2394 and Mast., the next 5 with Mast. and Tren. and so on.

#### DISCUSSION

The reason or reasons for the difference in results is not easily determined. There are, it seems to us, four major possibilities:

1. *Methods of testing.* We have outlined our indirect Coombs technique. The reactions with the anti-human globulin are based on time. If a serum contains two agglutinins, one strong and one weak, cells containing the antigen with which the first combines will be agglutinated within a minute by properly selected anti-human globulin serum, while, for other cells which combine with the second, agglutination will first become visible at 3 or 4 minutes and complete by 10 minutes. A number of bloods under test—in the present study, for example, about twenty—are set up side by side in the capillaries and under direct vision act as reaction time controls for one another. The difference between an immediate, one minute reaction and a delayed, three to 4 minute reaction is striking. We do not know if the same sharp distinction, indicating the presence of two antibodies of different specificity, is made by the test tube method in which anti-human

globulin is incubated with the washed, sensitized cells, spun and read; nor do we know whether, in a mass anthropological study, distinctions between strong and less strong Coombs reactions in the test tube would be made.

The value of the method is well illustrated in the next section on specificity of sera. It also served to indicate the falsity of the apparent indirect Coombs reactions referred to later in discussing unrecognized factors in the population. We would emphasize the importance, in doing any anthropological blood group study, of knowing one's reagents well—in this case the specific antibodies and the anti-human globulin serum.

2. *Differences in specificity of sera.* It is indeed unfortunate that the anti-*K* sera of the original study are no longer available, for the data in that study compared to the findings reported here suggest among other things, that they may have contained a second antibody that defines an antigen with practically a zero frequency in Whites but a significant frequency in Indians, an antibody comparable, for example, to anti-*Di*<sup>a</sup> and of equal value to anthropological genetics. That the second antibody was not anti-*Di*<sup>a</sup> we could prove: using anti-*Di*<sup>a</sup> we tested 39 of the Indians originally thought to be *K* + and found only 5 to be *Di*(<sup>a</sup> +), 4 of these being *K* - *k* + and one *K* + *k* +. It seems most unlikely that the contaminant was anti-*K*<sub>p</sub><sup>a</sup>, that defines a third allele at the *K*-*k* locus: Dr. Fred H. Allen Jr., sent us some anti-*K*<sub>p</sub><sup>a</sup> serum with which we tested 35 Cree Indians, close neighbors of the Chippewa, and found none positive, while he himself found no *K*<sub>p</sub>(<sup>a</sup> +) among 164 Peruvian Indians.

To carry the matter further we studied 21 indirect Coombs anti-*K* sera in our possession. None of these contain an antibody, other than anti-*K*, against the commonly recognized antigens, but when we ran indirect Coombs tests with them against three bloods, two of which—Freer and Woodw—contain a not commonly recognized antigen, and one—Goodsp

— an antigen of unproven specificity, we obtained the following results:

NO. OF SERA	TEST CELLS		
	Freer.	Gdspd.	Woodw.
16	—	—	—
1 (Gra)	+	—	—
4 (P 7801; Marn; Mast; Mar).	+	+	—

The phenotypes of these cells are:

Freer	O MMS P— ceddee	K—k+	Fy(a—)	Di(a—)	Le(a—)	K <sub>p</sub> (a—)
	Wr(a+).					
Gdspd	O MNS P+ CeDEe	K—k+	Fy(a+)	Di(a—)	Le(a—)	K <sub>p</sub> (a—)
	?+.					
Woodw	O MMs P+ ceddee	K—k+	Fy(a—)	Di(a—)	Le(a—)	K <sub>p</sub> (a+).

The first of these was kindly sent us by Ivor Dunsford as Wr(a+); we have no anti-*Wr*<sup>a</sup>, unless that is what the extra component of the last 5 anti-*K* sera defines, so that the *Wr*<sup>a</sup> status of Gdspd., and Woodw., is unknown. As to the second cells (Gdspd), it has been routine for several years in our laboratory when testing a blood for the presence of *K* to test with both anti-*K* (Mar) and anti-*K* (Ram). A very rare blood so tested reacts weakly with anti-*K* Mar both in saline and by indirect Coombs and not at all with anti-*K* Ram; it was the antigen so defined that the cells Gdspd contained. (Incidentally the blood of this child's non-identical twin reacted in the same way. The parents were not available for testing.) The third blood contains Allen's *K*<sub>p</sub><sup>a</sup> referred to above.

The reactions of one serum (Gra) with cells Freer, and of the 4 sera (P 7801, Marn. and Mast. of Levine, and our Mar) with cells Freer and cells Gdspd. were weak but reproducible. They were readily distinguishable from the strong reactions of the anti-*K* component by the method used. The reactions of Gra. with cells Freer were weaker than were the reactions of the other 4 sera, so that it is possible that the second antibody in Gra. is the same as in the others but was too weak to react with Gdspd. It may be that the second antibody in the 5 sera was anti-*Wr*<sup>a</sup> and the unidentified antigen in

Gdspd.  $W_r^a$ . In any case the point is that 5 of 21 anti- $K$  sera were found to contain at least one antibody in addition to anti- $K$ . Incidentally the three donors of the test cells were Caucasoids.

Of the sera used in this Indian study 4 (P 2394, Tren. and Rad. of Levine and our Ram.) reacted with  $K+$  cells and no other; Levine's Marn and Mast. and our Mar., as stated above, reacted weakly with cells Freer and Gdspd. With the Indian bloods they all gave strong reactions or none at all: there were no discrepancies.

3. *Unrecognized factors within a population at the time of study.* The blood samples of 3 of the 171 Indians tested in the first part of this study gave weak, 4 to 5 minute (see section on methods), indirect Coombs reactions. This was true whether the sensitizing serum was anti- $K$  or anti- $Di^a$  (which we were also running), while on the other hand none of them was agglutinated by the saline anti- $K$  (Mar.). Further tests showed these specimens were direct Coombs positive, the reaction starting at 4 to 5 minutes and becoming complete by 10 minutes. All three donors were in good health.

It seems to us possible that under some peculiar conditions, perhaps in the incubation period of an epidemic disease, the frequency of direct Coombs positive bloods might increase to a sizeable number. Unless the presence of such bloods was realized they might be read as indirect Coombs positive, with consequent distortion of figures.

4. *Methods of collection and handling of blood samples.* In the original study blood was obtained by skin puncture and the non-sterile specimens shipped to the laboratories of the two investigators. The antigenicity of the cells might have been affected in the two days or more between the taking and the testing of the blood. In the present study the specimens were collected on the Reserve in the morning and tested in the afternoon.

It has been our opinion for some time that the presence of the antigen  $K$  in a northern Indian population — and the

same is true for Eskimos — indicates the presence of White genes in that population. Dr. Fred H. Allen Jr. kindly allows us to quote the results of his unpublished study of Peruvian Indians: he tested around 300 with anti-*K*, finding no positives. We now await with the greatest interest the publication of the complete findings from Junqueira and Wishart's study of Brazilian Indians ('56).

#### SUMMARY

The Chippewa Indians of northern Minnesota were reported to have a *K*+ frequency of 10.7%, with a frequency that fell as the amount of Caucasoid admixture increased. On retesting, this was found not to be so, the frequency being probably less than 1%, while all those who were found to be *K*+ had at least one known White ancestor. It is thought probable that the anti-*K* sera used for the original study contained an antibody or antibodies in addition to anti-*K*. Tests proved that this could have been anti-*Di*<sup>a</sup>, and made it unlikely that it was anti-*K*<sub>p</sub><sup>a</sup>. Two other possible sources of error are suggested, namely the presence in the population of people whose blood gave a direct Coombs reaction which was mistaken for an indirect reaction, and contamination of the original specimens.

#### ACKNOWLEDGMENTS

We are indebted to many people: to Dr. F. J. Alcock of the National Museum of Canada for his continued support; to Dr. Matson and Dr. Levine for their willing and active cooperation; to Dr. H. Kleinman, Dr. Sidney Finkelstein, Dr. Wm. Ghrist, Mr. George Saunders, Mr. W. Parker Arthur and Mrs. Helen O'Dair for making arrangements for us on the Reserve and giving us every assistance. Last we owe a great deal to the members of the Chippewa tribe for allowing us to take and test their blood.



## LITERATURE CITED

- CHOWN, B., AND M. LEWIS 1951 The slanted capillary method of Rhesus blood grouping. *J. Clin. Path.*, *4*: 464-469.
- 1953 "Private" blood factors, homozygosis and the search for new blood groups. *Nature*, *171*: 700.
- 1956 The blood group genes of the Cree Indians and Eskimos of the Ungava district. *Am. J. Phys. Anthrop.*, *14*: 215-224.
- JONES, REV. PETER 1872 Peter Jones and the Ojebway Indians. A. W. Bennett, London.
- JUNQUEIRA, C. P., AND J. P. WISHART 1956 Blood groups of the Brazilian Indians (CARAJÁS). *Nature*, *177*: 40.
- MATSON, G. A., E. A. KOCH AND P. LEVINE 1954 A study of the hereditary blood factors among the Chippewa Indians of Minnesota. *Am. J. Phys. Anthrop.*, *12*: 413-426.
- MATSON, G. A., AND H. F. SCHRADER 1933 Blood grouping among the "Blackfeet" and "Blood" tribes of American Indians. *J. Immunol.*, *25*: 1-7.
- PANTIN, A. M., AND P. C. JUNQUEIRA 1952 Blood groups of the Brazilian Indians. *Am. J. Phys. Anthrop.*, *10*: 395-406.

## COMMENTS AND COMMUNICATIONS

---

### CONCURRENT FAT LOSS AND GAIN: ADDENDUM

HOWARD V. MEREDITH

*Iowa Child Welfare Research Station, State University  
of Iowa, Iowa City, Iowa*

In a recent issue of this JOURNAL Garn and Young ('56) reported a study on the thickness of the *telea subcutanea* at two sites in *Homo sapiens*. Their paper, entitled "Concurrent Fat Loss and Fat Gain," shows that "... fat on the anterior part of the leg *decreases* from the second to the fourth decade, while trochanteric fat markedly *increases* over the same time span."

As an addendum, it is pertinent to link the Garn-Young findings with certain findings on the human thorax and arm (Meredith, '35). The data yielding these thorax-arm results were collected 1930-34 on Iowa white males 12 to 18 years of age. Measures were obtained for thickness of the skin and subcutaneous tissue at anterior and posterior sites on the thoracic portion of the trunk and on the arm segment of the upper extremity. It will suffice to reproduce the central tendency values derived from analyses of the data taken at the posterior sites (table 1).

Examination of table 1 shows the trends for these measures of adipose tissue on the thorax and arm to diverge with advance in age. In the original report, curves are drawn to the series of means for each of the four sites studied, and the trend differences over the period from age 12 to age 18 years are summarized as follows: "... the curves for the two thorax measurements *ascend*, while the curves for the two arm measurements *descend*."

The foregoing findings on loss in arm fat concurrent with gain in thorax fat are specific for males. Boynton ('36) made a companion study on females and found increasing fat thickness between 12 and 18 years on the thorax and arm. The "contrasting trends" presented by Garn and Young "hold for both sexes." Colligating, present knowledge of human growth encompasses sex common and male specific instances of what Garn and Young refer to as the "fat loss during fat gain" phenomenon.

TABLE 1

*Average thickness of skin and subcutaneous fat at two sites on North American white boys 12 to 18 years of age*

AGE	NUMBER	POSTERIOR OF THORAX		POSTERIOR OF ARM	
		mean	Median	mean	Median
<i>years</i>		<i>millimeters</i>			
12	91	4.4	4.0	6.9	6.7
13	117	4.7	4.4	6.7	6.3
14	116	4.8	4.5	6.4	6.0
15	147	4.9	4.6	5.8	5.5
16	128	5.0	4.7	5.4	5.0
17	103	5.2	4.9	5.5	5.4
18	70	5.4	5.1	5.4	5.1

## LITERATURE CITED

- GARN, S. M., AND R. W. YOUNG 1956 Concurrent fat loss and fat gain. *Am. J. Phys. Anthropol.*, n.s. 14: 497-504.
- MEREDITH, H. V. 1935 The Rhythm of Physical Growth: A Study of Eighteen Anthropometric Measurements on Iowa City White Males Ranging in Age between Birth and Eighteen Years. *Univ. Iowa Studies in Child Welfare*, XI, 3: 1-128.
- BOYNTON, B. 1936 The Physical Growth of Girls: A Study of the Rhythm of Physical Growth from Anthropometric Measurements on Girls between Birth and Eighteen Years. *Univ. Iowa Studies in Child Welfare*, XII, 4: 1-105.

## BOOK NOTES

THE SEVEN CAVES. By Carleton S. Coon, pp. xx + 338, drawings, maps, plates. \$5.75. Alfred A. Knopf, New York. 1957.

Subtitled "Archaeological Explorations in the Middle East," this book recounts the experiences of Professor Conn, and various of his colleagues, on exploring expeditions of seven different caves from Tangiers to Afghanistan. While written for the layman interested in human prehistory, the descriptions are given in considerable detail and are an excellent summary of much of the work that Coon has done in this critical area of man's evolution. The difficulties, excitement and day-to-day problems of doing field work in prehistory are spelled out, yet the interpretation of the finds in light of the whole story of human history are not forgotten. As with all of Coon's books, this one is good reading.

F.P.T.

---

AN ETHNO-ATLAS. By Robert F. Spencer, pp. 42, \$1.50. Wm. C. Brown Company, Dubuque, Iowa. 1956.

The location of over 500 tribal, linguistic and racial groupings of anthropological importance are given in this atlas. The 11 outline maps in turn show the cultural areas and tribal groups, the language families and finally the racial distributions of mankind. While designed as the student manual for use in connection with introductory courses—and well fits this purpose—it is not in sufficient detail to meet the needs of specialists who may be interested in the precise present or historical locations of particular groups. Primary attention is given to ethnographical features, as the title indicates. One of the maps is devoted to racial distributions and only the major groups are shown. A list of 500 geographical place names, which may be frequently used in anthropological courses, arranged by continent and divided according to the geographical feature, is appended to the atlas.

F.P.T.

PREHISTORIC SETTLEMENT PATTERNS IN THE NEW WORLD. Edited by Gordon R. Willey, pp. 202. Viking Fund Publications in Anthropology, No. 23. Wenner-Gren Foundation for Anthropological Research, New York, 1956.

Twenty some authors have written short summary articles on the settlement patterns in each of many American regions which are known from archaeological work. While several large areas are not described, and in others the knowledge is scanty, on the whole this is the sort of treatment which can give the student of human population dynamics and genetics some foundation for improving his speculations on the nature and size of prehistoric populations. The detailed demography of early populations is unknown but by examining the inscriptions made by human occupation on the landscape we have the best hope of knowing something of the dynamics of these populations. In many of the papers the author gives his best estimate of the population sizes for several time horizons in the history of the area. Data of this sort are rare and useful even though they are only a "best guess."

F.P.T.

FORMATION ET TRANSFORMATION DES RACES. By Guy Dingemans, pp. 343. Librairie Armand Colin, 103 Boulevard Saint-Michel, Paris, 1956.

Interestingly subtitled *La Tragedie de L'Univers, Les Secrets de L'Homme, Origine de L'Espece Humaine*, as well as *Nouvelles Theories*, it is not surprising that this monograph does not fulfill its title objectives even though the author is imaginative. Together with an accompanying summary of a 32 page publication by the same author and publisher entitled *La Tragedie de L'Univers*, this publication attempts to tell the story of the formation of continents, species and of the human races. An example of the novel "theories" presented, and by no means the only one, is the notion that Australoids migrated across Antarctica into South America thus accounting for the Patagonians. While apparently well acquainted with the literature on the subjects treated, Dingemans is guilty of gross misinterpretations and distortions of the meanings of our knowledge about human history.

F.P.T.



HANDBOOK OF BIOLOGICAL DATA. Edited by William S. Spector, pp. xxxvi + 584. W. B. Saunders Co., Philadelphia. 1956.

This volume is a reference source, largely in tabular form, of data which has been prepared from the contributions of over 4000 scientists and reviewed with the counsel of an additional 13,000. It was prepared under the direction of a committee of the National Academy of Sciences and of the National Research Council using funds from the federal government. There are 445 tables grouped under 10 broad subject headings, of which "Genetics, Cytogenetics and Reproduction," and "Environment and Survival" are but two of use and special interest to human biologists. A truly monumental and encyclopedic accumulation of useful and accurate biological data.

F.P.T.

---

BIOCHEMICAL INDIVIDUALITY. By Roger W. Williams, pp. xi + 214, \$5.75. John Wiley & Sons, New York, 1956.

Each individual is biochemically unique. Professor Williams presents a summary of his extensive work on this subject and defends his thesis completely. While it is not new to show that some part of the total phenotype is highly variable, the documentation of biochemical individuality is of great value. As Williams has shown, this is often under direct genetic control and anthropologists should know of the potential value of biochemical genetics in the study of human variability. Williams' book, probably better than any other now available, can give this knowledge.

F.P.T.

---

THE ANCIENT MAYA. By Sylvanus Griswold Morley, Revised by George W. Brainerd, pp. x + 494, 3rd Ed., Stanford University Press, Stanford, Calif. 1956.

In 1954, George W. Brainerd began a revision of this standard work on the ancient Maya. It was completed following his death by Mrs. Betty Bell. The few parts dealing with the physical anthropology are the same as in the first edition.

F.P.T.

CUMULATIVE INDEX TO CURRENT LITERATURE ON ANTHROPOLOGY AND ALLIED SUBJECTS FOR 1955. Vol. 1, pp. 171. Department of Anthropology, Government of India, Indian Museum, Calcutta 13. 1956.

This is probably the only cumulative index of anthropological literature available today. It lists titles of articles from some 220 periodicals on anthropology and allied subjects. Physical anthropology and related biological subjects are well represented. A logically organized plan of contents and a subject and author index make the publication a truly useful one. The government of India is to be congratulated for supporting such a worthy enterprise, and we hope it will continue in future years.

F.P.T.

---

THE EFFECT OF EXPOSURE TO THE ATOMIC BOMBS ON PREGNANCY TERMINATION IN HIROSHIMA AND NAGASAKI. By J. V. Neel and W. J. Schull, pp. xvi + 241. Publication No. 461. National Academy of Sciences — National Research Council, Washington. 1956.

Professors Neel and Schull, and their collaborators, have made a pioneering study of two large urban populations to discover the effects of atomic irradiation on pregnancy terminations. The data are in unusual depth and cover a wide variety of observations or measurements. The carefully gotten data on consanguinity of parents or the pediatric examinations are but examples of the variety of information. Included are anthropometric values for weight, body length, head and chest circumference of 18,498 nine months old infants. The study is a pioneering one both from the standpoint of methodology and the kinds of data gathered. The difficulties of interviewing, describing and following up a large segment of an urban population have been admirably met. While this is not an anthropological study in any traditional sense, its methods of data gathering and analysis would very probably be valuable for the anthropological study of a population.

F.P.T.

GIFT TO THE UNIVERSITY OF PITTSBURGH  
by JOHN GILLIN

## THE BLOOD GROUPS AND HAEMOGLOBIN OF THE GORKHAS OF NEPAL<sup>1</sup>

G. W. G. BIRD, T. K. JAYARAM

*Armed Forces Medical College, Poona, India*

ELIZABETH W. IKIN, A. E. MOURANT

*Blood Group Reference Laboratory, Lister Institute, London, England*

AND

H. LEHMANN

*St. Bartholomew's Hospital, London, England*

Numerous blood group surveys have been carried out on the mainly Caucasoid peoples of central and western India and Pakistan, and show them on the whole to resemble the Mediterranean peoples, but to have higher M frequencies and much higher B frequencies than these. Studies have also been made of the blood groups of the Chinese and other Mongoloid peoples of western Asia, who show a completely different blood group picture. There are however a number of peoples who are of intermediate physical type and live in an intermediate zone, whose blood groups have been little studied. Among these are the Nepalese for whom only ABO blood group data have hitherto been available. Macfarlane ('37) tested 78 individuals, and Agar ('46) tested 2,869 Gorkha soldiers in India.

We have carried out tests on 200 soldiers from Nepal, carefully selected as belonging to the Gorkha caste. We have also extracted from the records of No. 2 British Base Transfusion Unit, situated at Dehra Dun during the second world war, the results of the ABO grouping of 2,809 Gorkha soldiers from Nepal. It was only when the present paper was almost complete that we became aware of the close correspondence between these results and those of Agar ('46). It appears probable that our 2,809 are included in his series but, as he

<sup>1</sup>A grant from the Wenner-Gren Foundation for Anthropological Research covers the cost of publishing this article.

gives only percentages and not numbers, and does not calculate gene frequencies, we have retained the results for the 2,809.

The blood specimens for the main series of tests were taken at Poona and sent by air to London. The red cells were tested for the antigens  $A_1$ ,  $A_2$ , B, M, N, S, Henshaw, Hunter, P, C,  $C^w$ , e, D, E, e,  $Lu^a$ , K and  $Fy^a$ . All were negative for Henshaw, Hunter,  $C^w$  and  $Lu^a$ . The specimens appeared to be in good condition and the internal consistency of the results for the ABO and Rh systems, with special reference to the  $A_1$  and e antigens, confirms this and makes it likely that results for the Kell and Duffy systems and especially the difficult P

TABLE 1  
*The A B O blood groups of 2,809 Gorkhas*

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	GENE FREQUENCIES	
O	893	.3179	.3189	895.8	A	.2450
A	949	.3378	.3367	945.7	B	.1903
B	709	.2524	.2512	705.6	O	.5647
AB	258	.0918	.0932	261.9		
Total	2,809	.9999	1.0000	2,809.0		1.0000

system, are reliable. The haemoglobin of all the bloods was tested by means of paper electrophoresis. All consisted entirely of haemoglobin A (normal adult haemoglobin).

The results of our tests are given in tables 1 to 8. For the  $A_1A_2BO$ , MNS and Rh systems gene frequency calculations were carried out by the method of Ceppellini, Siniscalco and Smith ('55).

There are no significant differences between the ABO blood group frequencies derived from the two series of tests described in this paper, nor between these and the results of Macfarlane's ('37) tests on 78 Nepalese. Reference has already been made to the relation between the present series of 2,809 ABO groupings and the results of Agar ('46). Macfarlane's tests on 56 Bhotias show an A frequency near that of the Nepalese, but a lower B frequency. For more distant

comparisons it is natural to refer on the one hand to the peoples of India and Pakistan and on the other to those of eastern Asia. Most of the comparative data are available in the works of Boyd ('39) and Mourant ('54).

TABLE 2  
*The A<sub>1</sub> A<sub>2</sub> B O blood groups of 200 Gorkhas<sup>1</sup>*

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	GENE FREQUENCIES	
O	55	.275	.2957	59.15	A <sub>1</sub>	.2306
A <sub>1</sub>	66	.330	.3118	62.36	A <sub>2</sub>	.0168
A <sub>2</sub>	5	.025	.0185	3.71	B	.2088
B	59	.295	.2706	54.12	O	.5438
A <sub>1</sub> B	15	.075	.0963	19.26	Total	1.0000
A <sub>2</sub> B	0	.000	.0070	1.40		
Total	200	1.000	.9999	200.00		

<sup>1</sup> These are not included among the 2,809 listed in table 1.

TABLE 3  
*The M N S blood groups of the Gorkhas<sup>1</sup>*

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	CHROMOSOME FREQUENCIES	
MMS	40	.200	.1968	39.37	MS	.1578
MsMs	56	.280	.2967	59.33	Ms	.5447
MNs	27	.135	.1399	27.98	NS	.0422
MsNs	62	.310	.2781	55.62	Ns	.2553
MNS	5	.025	.0233	4.67		
NsNs	10	.050	.0652	13.03		1.0000
Total	200	1.000	1.0000	200.00		

<sup>1</sup> All samples Henshaw-negative and Hunter-negative.

The frequency of the B gene in the Gorkhas is somewhat lower than in most Indian peoples; that of A is higher than in most Asiatic peoples except the Japanese and the Siamese; but A<sub>2</sub> is present, as it is in India. The M gene has a high frequency, as in India, and the total M gene frequency of the Gorkhas falls among the highest Indian figures. The frequency of the MS chromosome is slightly lower than in most Indian samples but still falls among the rather high fre-



quencies found in all Caucasoid peoples, and is very much higher than the values found in eastern Asia. The frequency of Ms is, however, higher than is known anywhere in India and is similar to that found in the Chinese who, on the other hand, almost completely lack MS.

TABLE 4  
*The Rh blood groups of the Gorkhas*<sup>1</sup>

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	FREQUENCY EXPECTED	NUMBER EXPECTED	CHROMOSOME FREQUENCIES
CCDEE	0	.000	.0001	0.01	CDE .0081
CCDEe	3	.015	.0120	2.39	CDe .7394
CCDee	107	.535	.5467	109.35	cDE .1794
CeDEE	0	.000	.0029	0.58	cDe .0731 <sup>2</sup>
CeDEe	53	.265	.2665	53.30	
CeDee	26	.130	.1081	21.62	1.0000
ccDEE	8	.040	.0322	6.44	
ccDEe	3	.015	.0262	5.25	
ccDee	0	.000	.0053	1.07	
Total	200	1.000	1.0000	200.01	

<sup>1</sup> All specimens were C<sup>w</sup>-negative.

<sup>2</sup> This may include some cde chromosomes.

TABLE 5  
*The P blood groups of the Gorkhas*

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	GENE FREQUENCIES
P+	88	.440	P .2517
P—	112	.560	p .7483
Total	200	1.000	1.0000

TABLE 6  
*The Kell blood groups of the Gorkhas*

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	GENE FREQUENCIES
K+	16	.080	K .0408
K—	184	.920	k .9592
Total	200	1.000	1.0000

The Rh frequencies are very close to those found for the Chinese, with CDe and cDE both more frequent than in India, and with cDE higher than in S.E. Asia but lower than the frequencies found in the Japanese which are the highest in Asia. Until larger numbers have been tested it cannot be determined how the 7% of cde and cDe chromosomes are divided between these two types, but in any case the frequency of cde is lower than in most Indian peoples.

TABLE 7  
*The Duffy blood groups of the Gorkhas*

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	GENE FREQUENCIES	
Fy(a+)	193	.965	Fy <sup>a</sup>	.8129
Fy(a—)	7	.035	Fy <sup>b</sup>	.1871
Total	200	1.000		1.0000

TABLE 8  
*The Lutheran blood groups of the Gorkhas*

PHENOTYPE	NUMBER OBSERVED	FREQUENCY OBSERVED	GENE FREQUENCIES	
Lu(a+)	0	.000	Lu <sup>a</sup>	.000
Lu(a—)	200	1.000	Lu <sup>b</sup>	1.000
Total	200	1.000		1.000

The P gene frequency is among the lowest known but somewhat higher than in the Chinese in whom it is the lowest yet found (Miller, Tannor and Hsu, '50). The Duffy (Fy<sup>a</sup>) gene has a high frequency, similar to those found in Pakistan, in Siam and among the Chinese (in America).

The relatively high frequency of the Kell gene found in the Gorkhas resembles rather that found in the Chenchus, the only Indian people hitherto tested, than the zero frequency shown in small samples of Chinese and of various peoples of south-east Asia. The absence of the Lutheran (Lu<sup>a</sup>) gene is in accordance with its absence or extremely low frequency in

other Asiatic populations tested, but the latter do not include the Chinese or the Japanese.

The absence of any abnormal haemoglobins recognisable by electrophoretic tests contrasts with the presence of haemoglobin E in most peoples so far tested in south-east Asia, and of haemoglobin S in the Vedddoid tribes of the Nilgiri Hills. Among the inhabitants of north-west India about 3% of persons have haemoglobin D. Apart from very rare examples of haemoglobin H the Chinese appear to have only haemoglobin A. No results of haemoglobin tests on Japanese are known to us. A summary of the present state of our knowledge of the distribution of the haemoglobins is given by Lehmann ('57).

Taking the results for the Gorkhas as a whole it may be said that they are intermediate between the findings for the settled peoples of India and those for the peoples of eastern Asia, especially the Chinese and the Japanese. There is no suggestion of any particularly close connection with south-eastern Asia; our knowledge of the blood groups of the peoples living to the north and north-east of Nepal is too slight to allow detailed comparisons.

---

We should like to thank Dr. Ada C. Kopeć for carrying out the gene frequency calculations.

#### SUMMARY

Blood samples from 200 or more Gorkhas have been examined for haemoglobin variants and for the antigens of the ABO, MNS, P, Rh, Lutheran, Kell and Duffy blood group systems. No haemoglobin other than A was found. The blood group frequencies are in general intermediate between those found in India and those characteristic of eastern Asia.

#### LITERATURE CITED

- AGAR, W. T. 1946 Nepali blood groups. *Nature*, London, 157: 270.  
BOYD, W. C. 1939 Blood Groups. *Tabul. Biol.*, 17: 113-240.

- CEPPELLINI, R., M. SINISCALCO AND C. A. B. SMITH 1955 The estimation of gene frequencies in a random mating population. *Ann. Hum. Genet.*, 20: 97-115.
- LEHMANN, H. 1957 Haemoglobin and its abnormalities. *Practitioner*, 178: 198-214.
- MACFARLANE, EILEEN W. E. 1937 Eastern Himalayan blood groups. *Man*, 37: 127-129.
- MILLER, E. B., H. D. TANNOR, AND C. F. HSU 1950 The P factor and its variants in Caucasians, Negroes and Chinese. *J. Lab. Clin. Med.*, 36: 230-233.
- MOURANT, A. E. 1954 The distribution of the human blood groups. Oxford. Blackwell Scientific Publications.





# VARIATION IN FACIAL AND PUBIC HAIR GROWTH IN WHITE WOMEN

P. KYNASTON THOMAS<sup>1</sup> AND D. G. FERRIMAN

*North Middlesex Hospital, London, England*

TWO FIGURES

## INTRODUCTION

As a necessary preliminary to an investigation into the clinical significance of excessive hair growth in women (Ferriman, Thomas and Purdie, '57), observations were made on the normal variability of facial and pubic hair growth in women and its alteration with age. The results obtained form the subject of this communication.

Previous investigations in this direction, such as those of Trotter and Danforth ('22) and Dupertuis, Atkinson and Elftman ('45), have stressed the frequency with which departures from what is normally considered to be the "feminine" distribution of hair are encountered. In this, it is normally pictured that beard, moustache and body hair are absent or scanty and that the pubic hair possesses a horizontal upper border. Studies on the age changes in hair growth, with the exception of that of Trotter ('21), have largely been confined to those occurring during adolescence.

## MATERIAL AND METHODS

Hair in the human adult has been subdivided, largely on the basis of gross size, into two main types, the downy vellus hair and the coarser terminal hair, although the two grade into one another and both may be produced by the same follicle. It is the latter type that has been examined in this investigation. Garn ('51) has recognized six morphological types of terminal

<sup>1</sup> Present address: Department of Anatomy, University College, London, England.

hair which correspond to the following sites of hair growth: head hair; eyebrow and eyelash hair; moustache and beard hair; body hair; pubic hair; axillary hair.

It was decided to restrict the study to that of facial and pubic hair growth. The investigation was performed on hospital patients. This included every patient between the ages of 15 and 84 admitted to the general medical and surgical wards, two geriatric wards and the tuberculosis wards of the North Middlesex Hospital during a period of four months, and every patient seen at one general medical out-patient clinic for a somewhat longer period. Patients with diseases which were considered to have a possible influence on hair growth, such as myxoedema, were excluded. Altogether 584 women were examined. For convenience of presentation they have been divided into age groups by decades (table 1). Since a number of patients had been shaved for abdominal operations before being seen, the number of observations on abdominal hair growth is smaller than that for the lip and chin.

TABLE 1  
*Numbers of subjects studied by decades*

AGE GROUP	NUMBERS OF PATIENTS	
	Lip and chin	Lower abdomen
15-24	98	82
25-34	85	80
35-44	86	78
45-54	118	109
55-64	85	72
65-74	68	60
75-84	44	43

Methods of grading hair growth have usually been based upon a subjective estimate, as in the investigations of Danforth and Trotter ('22), Dupertuis, Atkinson and Elftman ('45), Garn ('51) and Reynolds ('51). Hamilton ('51), in a study of axillary hair growth, shaved and weighed the hair, a more accurate method, but one with practical limitations in some types of investigation. In this study, the method of subjective assessment of hair growth had to be employed.

Five grades of hair growth were distinguished at each of the three sites. The first grade (0) was an absence of hair apart from the usual downy growth of vellus hair. Minor degrees of hair growth were found to be common at all three sites and these constituted grades 1 and 2. More severe degrees were placed in grades 3 and 4. Sketches showing the approximate severity of each grade are shown in figure 1 and their descriptions are given in table 2. Intermediate variations obviously occur and some degree of judgment had to be used in deciding which grading these should be given, but independent gradings of the same subjects made by the two observers showed good correspondence.

TABLE 2  
*Criteria adopted for grading hair growth*

---

*Upper lip*

- Grade 1: a few straggling hairs at the outer margin.
- Grade 2: a few hairs at the outer margin arranged, however, in the form of a small moustache.
- Grade 3: a definite moustache extending from the outer margin half-way to the mid-line.
- Grade 4: a frank moustache reaching virtually to the mid-line.

*Chin*

- Grade 1: a few scattered hairs.
- Grade 2: a few scattered hairs with one or two concentrations.
- Grade 3: a definite but still scanty beard.
- Grade 4: a frank beard.

*Abdomen*

- Grade 1: a few hairs scattered in a vertical line between the centre of the pubic region and the umbilicus.
  - Grade 2: a definite streak of hairs confined to this line.
  - Grade 3: a thin band of hair arranged on either side of this line.
  - Grade 4: an inverted V-shaped growth of hair with its apex at the umbilicus and its base over the pubis.
- 

Classifications of pubic hair growth have previously been made by Dupertuis, Atkinson and Elftman ('45) and Lindgård et al. ('56). Dupertuis et al. classified pubic hair growth as horizontal when there was no upward extension towards

the umbilicus, sagittal when this extension was limited to the midline and acuminate when it formed an inverted V-shaped growth. In addition they described a heavier growth found only in men which they termed disperse. This classification corresponds approximately with the one adopted in the present investigation, the horizontal pattern being equivalent to

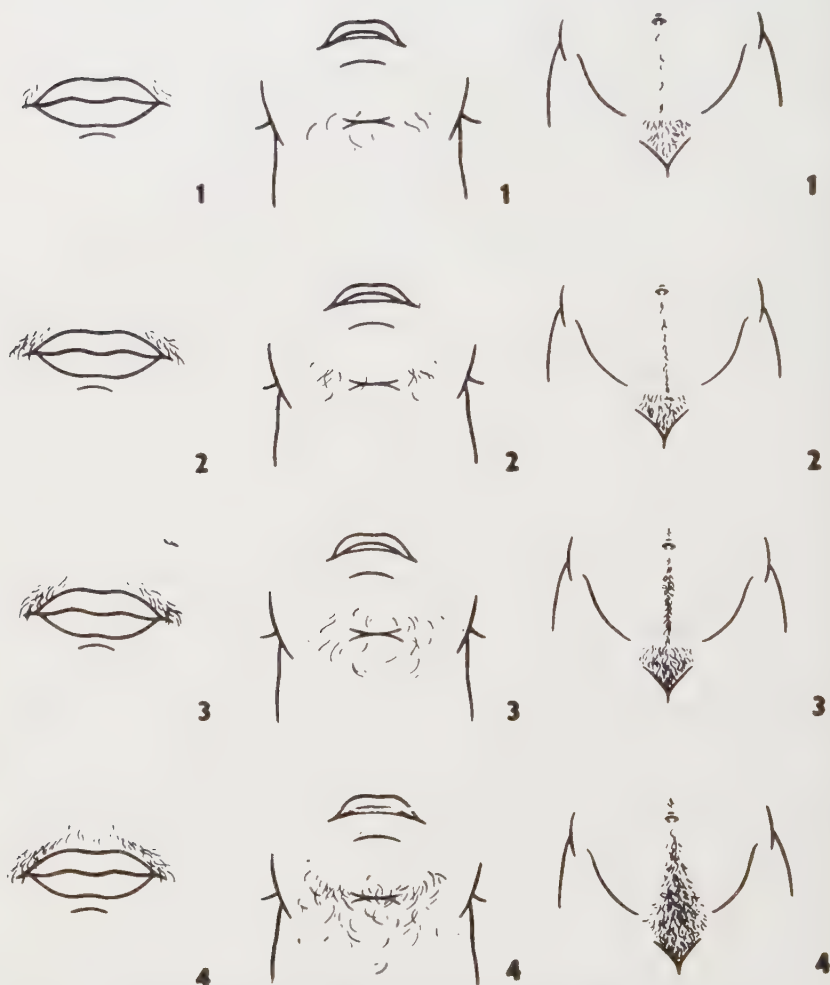


Fig. 1 Sketches illustrating grading adopted for degrees of hair growth on lip, chin and lower abdomen.

grade 0, the sagittal to grades 1, 2 and 3 and the acuminate to grade 4. A somewhat different classification was utilized by Lindegård et al. ('56), but was felt not to be as useful for the present purpose.

## RESULTS

The results obtained from the grading of the degree of hair growth on the lip, chin and lower abdomen in 269 subjects between the ages of 15 and 44 are displayed in table 3. The incidence of hirsuties on the chin is lower and hence the figures for grades 1 and 2 have been combined as have those for grades 3 and 4.

It will be observed that grade 0 is clearly the commonest appearance at all three sites and that hair growth varies continuously between the two extremes, the numbers presenting the different degrees of growth becoming progressively smaller the more extensive is the growth. The incidence of a substantial degree of hair growth over this age range, however, is appreciable. In the 15-24 age group, 16% of individuals show a grade 3 or 4 growth at one or more sites and the figures for the 25-34 and 35-44 groups are comparable, being 11% and 13% respectively.

TABLE 3  
*Frequency distribution of degrees of facial and abdominal hair growth*

LIP	0	1	2	3	4	TOTAL
15-24	72	16	5	5	0	98
25-34	57	15	10	3	0	85
35-44	53	14	10	6	3	86
<i>Total</i>	<i>182</i>	<i>45</i>	<i>25</i>	<i>14</i>	<i>3</i>	<i>269</i>
CHIN						
15-24	96	2		0		98
25-34	72	7		6		85
35-44	76	6		4		86
<i>Total</i>	<i>244</i>	<i>15</i>		<i>10</i>		<i>269</i>
ABDOMEN						
15-24	58	10	5	8	1	82
25-34	54	10	10	4	2	80
35-44	65	2	5	4	2	78
<i>Total</i>	<i>177</i>	<i>22</i>	<i>20</i>	<i>16</i>	<i>5</i>	<i>240</i>



The degree of facial and lower abdominal hair growth shows considerable variation with age and hence it is important for such changes to be taken into consideration in any study on the correlation between hair growth and other physical characteristics. In table 4 are given the relative incidences of minor (grades 0-2) and major (grades 3 and 4) degrees of hair growth on the lip, chin and lower abdomen by decades, and the variation with age in the incidence of the latter at these sites is shown graphically in figure 2.

The incidence of lower abdominal hirsuties remains approximately constant in the younger age groups and then suddenly falls in the 45-54 age group. A grading above 0 is found in only one patient over the age of 54. In contrast, the incidence of facial hirsuties shows only a slight increase over the earlier decades, but rises sharply after this time.

TABLE 4

*Changes in the incidence of facial and hypogastric hirsuties with age  
(numbers of observations and percentage incidences for decade groups)*

AGE GROUP	LIP		CHIN		ABDOMEN	
	0-2	3-4	0-2	3-4	0-2	3-4
15-24	93	5	98	0	73	9
	95%	5%	100%	0%	89%	11%
25-34	82	3	79	6	74	6
	96.5%	3.5%	93%	7%	92.5%	7.5%
35-44	77	9	82	4	72	6
	89.5%	10.5%	95.5%	4.5%	92.5%	7.5%
45-54	108	10	111	7	108	1
	91.5%	8.5%	94%	6%	99%	1%
55-64	74	20	81	13	83	0
	79%	21%	86%	14%	100%	0%
65-74	47	21	57	11	60	0
	69%	31%	84%	16%	100%	0%
75-84	29	15	26	18	43	0
	66%	34%	59%	41%	100%	0%

## DISCUSSION

An extensive previous investigation on hair growth in women is that of Dupertuis et al. ('45), who studied sex differences in pubic hair distribution. Pubic hair growth, as previously discussed, was classified as horizontal, sagittal or

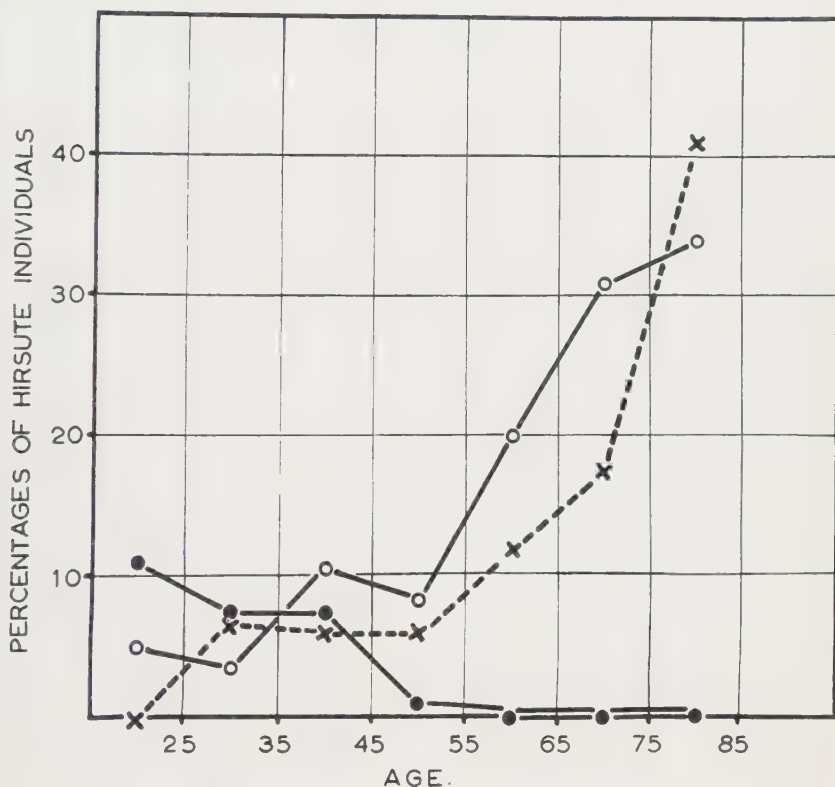


Figure 2

acuminate. Their findings for the incidence of an acuminate pattern of hair growth, which were for white American women, are higher than that obtained here, whereas the incidence of a sagittal pattern was considerably lower. The latter difference is possibly attributable to the fact that their observations were made on photographs. Trotter and Danforth (22) as-

sessed the incidence of facial hypertrichosis in a large series of American women and obtained a figure of 27%. These and other investigations, such as that of Rodecurt ('34), have demonstrated that a substantial proportion of women show a degree of hair growth that departs from the "feminine" distribution.

Dupertuis et al. ('45) compared abdominal hair growth with body hair in general, taking as an index of this growth of hair on the chest and thighs and found an approximate correlation between the two. No systematic correlation between abdominal and facial hair growth and general body hair was attempted in the present investigation, but a strong impression was gained that the heavier degrees of general hirsuties in younger women are found in those presenting the major grades of abdominal and facial hirsuties. Studies made by Priesel and Wagner ('30) and Greulich ('42) have demonstrated that the horizontal type of pubic hair growth appears in both sexes at puberty. Similarly, Dupertuis et al. found that two out of every five adolescent males presented a horizontal pubic hair line, but that this fraction fell to one in six of males between the ages of 30 and 40. Similar findings were obtained by Reynolds ('51). About one in ten of the adolescent females and a slightly lower proportion of females aged between 31 and 40 examined by Dupertuis et al. presented an acuminate abdominal hair growth. Thus they concluded that the horizontal type of pubic hair growth is the basic pattern from which the others develop by upward extension and that the retention of this pattern in most adult women seems to be "a result of the general feminine characteristic of paucity of body hair rather than a special factor affecting the pubic region." In other words, it follows that body hair growth in both sexes should be thought of in terms of degree rather than of distribution.

Observations on hair growth in the older age groups in women are scanty. The growth of axillary hair was found to decline abruptly at about the time of the menopause by Hamilton ('51), but no observations on pubic hair were made. How-

ever, a reduction of axillary hair growth in the older age groups in men was found by Hamilton and also by Heller and Shipley ('51) and these latter authors observed that this was accompanied by a similar change in pubic hair growth. There are indications that the reduction in axillary hair growth actually coincides with the menopause for Hamilton found that at the chronological age when the menopause occurs, the weight of axillary hair is less in women who no longer menstruate than in those who have continued to do so. Our findings with respect to facial hair growth differ somewhat from those obtained by Trotter ('21), who found that the incidence of facial hypertrichosis gradually increased from youth to old age without a conspicuous change at any particular period. This conclusion was reached from a study on the length and diameter of the hairs on the upper lip and cheek in white and colored American women, when it was found that the average length and diameter of the hairs at these sites both showed a progressive increase with age.

The explanation of the changes in hair growth that occur in later life has so far not been elucidated. It is of interest that there is a decline in the degree of growth of body, pubic and axillary hair in both men and women in later life and that the increased growth of facial hair is also seen in both sexes (Trotter, '21).

#### ACKNOWLEDGMENTS

We wish to thank Dr. Mildred Trotter for helpful advice and criticism and the members of the staff of the North Middlesex Hospital who permitted us to examine patients under their care. One of us (P.K.T.) was in receipt of a grant from the North Middlesex Hospital Research Fund during the course of this work. Figure 1 was prepared by Miss D. M. Barber.

#### SUMMARY AND CONCLUSIONS

A system of grading of facial and pubic hair growth is described and the results of the examination of 584 hospital patients between the ages of 15 and 84 presented. In the

younger age groups (15-44), the existence of a substantial proportion of individuals who depart from what is ordinarily considered to be the "feminine" pattern of hair growth is confirmed. It is likely that the differences in body hair growth between males and females are a matter of degree rather than a reflection of a more fundamental difference in hair distribution.

After the fifth decade, there is a striking increase in the incidence of facial hirsuties and, at the same time, a reduction in the degree of pubic hair growth.

#### LITERATURE CITED

- DANFORTH, C. H., AND M. TROTTER 1922 The distribution of body hair in white subjects. *Am. J. Phys. Anthropol.*, 5: 259-265.
- DUPERTUIS, C. W., W. B. ATKINSON AND H. ELFTMAN 1945 Sex differences in pubic hair distribution. *Human Biol.*, 17: 137-142.
- FERRIMAN, D. G., P. K. THOMAS AND A. W. PURDIE 1957 Constitutional virilism in women. In preparation.
- GARN, S. M. 1951 Types and distribution of the hair in man. *Ann. N. Y. Acad. Sci.*, 53: 498-507.
- GREULICH, W. W. 1942 Somatic and endocrine studies of pubertal and adolescent boys. *Monog. Soc. Res. Child Dev.*, 7: No. 3.
- HAMILTON, J. B. 1951 Quantitative measurement of a secondary sex character: axillary hair. *Ann. N. Y. Acad. Sci.*, 53: 585-599.
- HELLER, A. L., AND R. A. SHIPLEY 1951 Endocrine studies in aging. *J. Clin. Endocrinol.*, 11: 945-962.
- LINDEGÅRD, B., C. MORSING AND G. E. NYMAN 1956 Male sex characters in relation to body-build, endocrine activity, and personality. In "Body-Build, Body-Function and Personality" ed. Lindegård. Lund: Gleerup.
- PRIESEL, R., AND R. WAGNER 1930 Gesetzmäßigkeit im Auftreten der extragenitalen sekundären Geschlechtsmerkmale bei Mädchen. *Zeit. f. Konst.*, 15: 333.
- REYNOLDS, E. L. 1951 The appearance of adult patterns of body hair in man. *Ann. N. Y. Acad. Sci.*, 53: 576-584.
- RODECURT, M. 1934 Beobachtung über Nabel und Körperbehaarung beim Weibe. *Zeit. f. Konst.*, 18: 373.
- TROTTER, M. 1921 A study of facial hair in the white and negro races. *Washington Univ. Stud.*, 9: 273-289.
- TROTTER, M., AND C. H. DANFORTH 1922 The incidence and heredity of facial hypertrichosis in white women. *Am. J. Phys. Anthropol.*, 5: 391-397.



# BILATERAL ASYMMETRY IN SKELETAL MATURATION OF THE HAND AND WRIST: A ROENTGENOGRAPHIC ANALYSIS

MELVYN J. BAER AND JOSEPHINE DURKATZ

*The Merrill-Palmer School, Detroit, Michigan*

## INTRODUCTION

In the study here reported, bilateral asymmetry in the rate of maturation of the skeletal components of the hand and wrist was investigated. The method used was to determine the bilateral differences in maturational status of each of the carpal bones and of the bony epiphyses, through comparisons of radiographs of the right and left hands of the same individuals. For the purpose of this analysis, the developmental status of each center of ossification was assessed in terms of the maturational stages described by Greulich and Pyle ('50). An asymmetry was found to exist when the osseous units representing the same bone were assigned to different stages in each hand. This procedure, later described more fully, served as the basis for quantifying the observed qualitative difference in form of the bones bilaterally, and facilitated statistical treatment of the data.

Although many writers have noted the presence of bilateral asymmetries in growth or maturation, often incidental to their investigation of other aspects of skeletal development, quantitative data have been reported infrequently in the literature. Long and Caldwell ('11), Pryor ('16), Köhler ('24), Bardeen ('21), Sawtell ('29), Flecker ('32, '42), Torgersen ('51), Acheson ('52), and Watson and Lowrey ('54), among others, have reported observing bilateral differences in the number of bony centers present. However, they either present data collectively for each side of the body or offer

numerical data concerning specific centers for only a few individuals. Borovansky and Hnevkovsky ('29), for example, cite the instance of twin brothers manifesting different asymmetrical patterns of onset of ossification in the wrist.

Menees and Holly ('32) and Elgenmark ('46), however, present data detailing specific occurrences of asymmetry in the extremities of populations respectively of newborn infants and young children. Menees and Holly studied a population of 500 white American infants within the first 48 hours after birth. Unilateral presence of an epiphysis or a round bone was observed occurring 32 times in this series. Asymmetry was found to be slightly more prevalent in the males (7.22% of the subjects showing an asymmetry) than in the females (5.49%) and was three times more frequent in the upper extremities (24 instances) than in the lower (8 instances). Elgenmark analyzed the bilateral appearance of ossification centers in 59 Scandinavian children (28 boys, 31 girls) ranging in age from 4 to 60 months. He reports finding 13 instances of the unilateral presence of centers of ossification in each sex. Of particular interest is the fact that all the centers causing deviation between the right and left sides of the body were located in the hands or feet, with the exception of the greater trochanter and the proximal epiphysis of the radius. Elgenmark concludes that bilateral differences in appearance of centers of ossification tend to be localized in the epiphyses of the phalanges and are a function of generally greater variability in the time of appearance of these bones.

The unilateral presence of paired centers of ossification has also been observed and reported for the prenatal period. The work of Noback and Robertson ('51), reporting the appearance of centers of ossification during the first 5 prenatal months, lists 18 instances of the unilateral presence of the diaphysis of a metacarpal, a metatarsal, or a phalanx in a series of 136 embryos and fetuses.

While these investigators have been concerned with rates of maturation, as shown by the presence or absence of centers

of ossification, others have directed their attention to the study of asymmetry of *growth* by measuring size differences between the bones already present in both hands. Baldwin ('21), Allen ('26), and Baldwin, Busby and Garside ('28) measured the surface areas of the carpal bones through the use of a planimeter. Sawtell ('29) measured the widths of the distal ends of the shafts of the radii and ulnae in both hands. Allen concluded that growth of the carpal bones may vary widely in the right and left wrists of the same individuals. Baldwin ('21) and Baldwin, Busby and Garside ('28) present the qualification that in neither sex is there any significant difference between the carpal areas of the right and left hands as indicated by the averages at various ages. Sawtell also concluded that, on the average, there are no real differences between the size of the radial and ulnar epiphyses and diaphyses in the right and left wrists.

Certain limitations are evident in the methods used to investigate bilateral asymmetry of either the maturation or the growth of the skeleton. Thus, the technique of noting only the presence or absence of a center of ossification restricts the investigation to the initial stage of maturity. It fails also to take into consideration those instances where the center is present in both hands but differs in form or in the configuration of the articular margins. Moreover, though the technique of measuring the surface areas of the bones offers a means of quantifying size asymmetries in the carpal region, it is of less use in assessing size differences in the epiphyses of the metacarpals and the phalanges. The analysis of size difference obviously cannot be used as a substitute for determination of maturational status, since two bones may have the same surface area and yet differ in form or proportion. Further, the procedure of grouping the data for each side of the body and comparing the averages (for example, the average number of bones present on each side of the body) eliminates compensating differences and obscures asymmetries actually present in the component members of the population studied.

The present investigation attempted to answer, within the limits of the data and the methods employed, the following questions:

1. What is the frequency of occurrence of maturational asymmetries in the carpal bones and epiphyses of the hand and wrist?

2. How does the variability in time of onset of ossification reported in the literature (Pyle and Sontag, '43) for the carpal bones and epiphyses of the left hand compare with the frequency of bilateral asymmetries in the same bones? In other words, are those bones which are most variable in time of appearance in the left hand also the most likely to show bilateral asymmetry?

3. Is there a sex difference in the incidence of maturational asymmetries?

4. Does skeletal maturation advance more rapidly in one hand than in the other?

#### MATERIALS AND METHODS

*The sample.* The data used in this study comprise a series of 474 roentgenograms of both hands and wrists taken on a population of 123 boys and 122 girls. The subjects were enrolled in the Infant Service, Nursery School, or Clubs Service of The Merrill-Palmer School in the years 1929-1933 and 1950-1955. Of the total 245 children, 239 were Caucasians, 5 were Negroes, and 1 was Mongolian. All the children were considered to be in good health at the time the data were collected. All came from families of middle and upper socioeconomic status. Although the number of roentgenograms averages nearly two films per child, 111 children are represented by a single film, while children in the numbers of 69, 37, 26, and 2 are represented by 2, 3, 4, and 5 films, respectively.

*Method of assessing maturational status.* The method used to assess the maturity of the individual bones is based on the definitions of maturational stages described and illustrated by Greulich and Pyle ('50). However, since the present investigation was concerned with the occurrence of asym-



metries during the early phases of skeletal development, only the first three stages defined by these writers were employed. In order to record the unilateral presence of a bone, a stage "O" was established to denote the absence of a center of ossification. Although the precise definition of each stage as formulated by Greulich and Pyle is stated in terms of the individual bones, and in some instances is modified according to the bone under consideration, it is possible to paraphrase a general description characterizing each of the first three stages of maturity as follows:

Stage I is characterized by the initial appearance of the center of ossification.

Stage II is attained when the bone nodule is rounded and its margins are smooth (in the case of the carpal bones and the epiphyses of the metacarpals), or when the epiphysis is disk-shaped and its margins are smooth (in the case of the phalanges).

Stage III is reached when the articular surfaces begin to differentiate (carpal bones); or when the epiphysis begins to flatten to conform to the shape of its diaphysis (metacarpals); or when the central portion of the growth cartilage plate attains its definitive thickness (metacarpals and phalanges); or when the epiphysis is half as wide as the diaphysis (phalanges).

The procedure used in assessing the films, each showing the right and left hands, consisted of assigning each bone an independent rating in terms of the scale of stages from 0 through III. In some instances, bones adjudged to be in stage IV or beyond, according to the criteria of the Greulich and Pyle Atlas, were also assigned to stage III. This procedure was found necessary to allow for instances in which a center of ossification assigned to one of the first three stages (0-I-II) in one hand was advanced beyond stage III in the other. Roentgenograms in which all the epiphyseal and carpal centers were in stage III or beyond were excluded. No at-



tempt was made to discriminate between two bone centers representing different developmental levels within a given stage (Acheson, '54). Films of the right and left hands for each child were read at the same time.

*Observer reliability in assessing symmetry versus asymmetry.* All the roentgenograms used in this study were assessed by one reader who had had no previous experience in assessing hand films by the more frequently used method of determining skeletal age. Fifty roentgenograms, selected

TABLE 1  
*Observer agreement and disagreement between the first and the second assessments of 196 pairs of bones*

		FIRST ASSESSMENT			SECOND ASSESSMENT TOTALS
		Right hand advanced	Hands sym- metrical	Left hand advanced	
SECOND ASSESSMENT	Right hand advanced	13	11	1	25
	Hands symmetrical	5	132	9	146
	Left hand advanced	5	6	14	25
	First assessment totals	23	149	24	196

at random, were reassessed by the observer after a lapse of several weeks. Since the present study is not concerned primarily with the stages of development of the individual bones per se, but rather with the determination of the presence or absence of symmetry, the test series were analyzed with respect to the following factors: (1) Observer reliability in duplicating an initial judgment that given pairs of bones of the right and left hands are symmetrical or asymmetrical in development (regardless of the particular stage or stages assigned in either the first or second judgment). (2) Observer consistency in determining direction of asymmetry; i.e., if the bones of the right and left hands were

judged to be asymmetrical in the first assessment, was the bone of the *same hand* considered to be most advanced in the second assessment?

The extent of agreement of the first and the second assessments in judging the 196 pairs of bones present in the test series of 50 roentgenograms is shown in table 1. For example, in the first assessment, the bone in the right hand was judged to be in advance maturationally of the corresponding bone in the left hand in 23 instances, while in 149 instances the bones were judged to be symmetrical; and in 24 instances the bone in the left hand was judged to be in advance of the corresponding bone in the right hand. The comparable figures for the second assessment are 25, 146, and 25, respectively. The expected agreement in recognizing symmetry as well as the direction of asymmetry would be 59.68%, as calculated from the marginal totals. The actual or observed agreement, 81.12% is significantly higher ( $p$  is less than 0.01) than the expected agreement, according to the ratio of the difference between these two percentages to the standard error of the difference, 4.48.

### *Findings*

Tables 2 and 3 list the order of appearance and the standard deviations for onset of ossification of the epiphyses of the hand and the carpal bones for boys and girls, respectively (based on data reported for the left side of the body by Pyle and Sontag, '43). The incidence and frequency (percentage) of occurrence of bilateral asymmetries observed in the present study are recorded for the individual bones in columns 2 and 4 of the tables. Percentage of asymmetry is recorded only for those bones for which 10 or more observations were obtainable.

In both sexes the carpal bones, taken as a group, show the highest percentage of asymmetry. For the boys, the carpal bones have an average asymmetry of 45.84%, while the epiphyses of the hand, in instances for which data are available, show an average asymmetry of 24.80%. The comparable

figures for the girls are 41.46% and 24.59%, respectively. These findings concerning the foci of greatest asymmetry parallel Pyle and Sontag's ('43) conclusion that the carpal bones tend to show greater variability in onset of ossification than the epiphyses of the long bones of the hand.

TABLE 2

*Frequency of bilateral asymmetries in the maturation of the bones of the hand and wrist: boys*

BONE CENTER <sup>1</sup>	VARIABILITY <sup>1</sup> OF ONSET OF OSSIFICATION (SD IN MONTHS)	(1) PAIRS OF HANDS SYM- METRICAL	(2) PAIRS OF HANDS ASYM- METRICAL	(3) TOTAL (1) + (2)	(4) PERCENTAGE OF ASYMMETRY (2) / (3)
Capitate	1.8	2	1	3	...
Hamate	2.2	2	0	2	...
Distal radius	4.7	0	2	2	...
Proximal 3rd finger	5.3	3	0	3	...
Proximal 2nd finger	5.0	3	0	3	...
Proximal 4th finger	5.4	3	2	5	...
Metacarpal II	5.1	1	1	2	...
Distal 1st finger	6.2	5	0	5	...
Metacarpal III	6.4	3	3	6	...
Proximal 5th finger	5.6	12	2	14	14.3
Metacarpal IV	7.1	18	5	23	21.7
Middle 3rd finger	7.6	40	7	47	14.9
Middle 4th finger	7.8	41	8	49	16.3
Metacarpal V	8.0	24	11	35	31.4
Middle 2nd finger	7.5	48	10	58	17.2
Triquetral	15.9	76	24	100	24.0
Distal 3rd finger	6.4	33	8	41	19.5
Distal 4th finger	7.0	39	8	47	17.0
Metacarpal I	7.3	42	24	66	36.4
Proximal 1st finger	7.9	76	16	92	17.4
Distal 2nd finger	7.9	59	26	85	30.6
Distal 5th finger	7.4	73	18	91	19.8
Middle 5th finger	11.7	69	18	87	20.7
Lunate	19.3	63	33	96	34.4
Navicular	14.1	15	18	33	54.5
Greater multangular	19.7	12	20	32	62.5
Lesser multangular	15.2	12	14	26	53.8
Distal ulna	10.6	3	7	10	70.0

<sup>1</sup> Bones are arranged in order of appearance of the centers of ossification in the left hand; taken from data listed in table 1, Pyle and Sontag ('43).

In order to determine the degree of relationship between the three variables: (1) order of appearance of centers of ossification, (2) variability of onset of ossification as expressed by the standard deviation, and (3) percentage of bilateral asymmetry, Spearman rank order correlation coefficients were calculated from the data listed in tables 2 and 3. The cor-

TABLE 3

*Frequency of bilateral asymmetries in the maturation of the bones of the hand and wrist: girls*

BONE CENTER <sup>1</sup>	VARIABILITY <sup>1</sup> OF ONSET OF OSSIFICATION (SD IN MONTHS)	(1) PAIRS OF HANDS SYM- METRICAL	(2) PAIRS OF HANDS ASYM- METRICAL	(3) TOTAL (1) + (2)	(4) PERCENTAGE OF ASYMMETRY (2)/(3)
Capitate	2.1	1	0	1	...
Hamate	2.3	1	0	1	...
Proximal 3rd finger	3.1	4	0	4	...
Distal radius	4.4	1	3	4	...
Proximal 2nd finger	3.0	4	0	4	...
Proximal 4th finger	3.2	4	0	4	...
Distal 1st finger	5.0	4	1	5	...
Metacarpal II	3.7	4	1	5	...
Metacarpal III	4.0	6	0	6	...
Proximal 5th finger	4.2	4	1	5	...
Middle 4th finger	4.8	12	0	12	0.0
Middle 3rd finger	4.9	12	0	12	0.0
Metacarpal IV	4.1	4	1	5	...
Metacarpal V	4.7	2	2	4	...
Middle 2nd finger	5.2	13	2	15	13.3
Distal 4th finger	5.9	6	4	10	40.0
Distal 3rd finger	3.9	8	0	8	...
Metacarpal I	5.3	15	6	21	28.6
Proximal 1st finger	5.1	17	6	23	26.1
Triquetral	13.7	46	20	66	30.3
Middle 5th finger	7.9	35	10	45	22.2
Distal 5th finger	7.0	26	4	30	13.3
Distal 2nd finger	6.9	22	7	29	24.1
Lunate	14.2	81	23	104	22.1
Greater multangular	14.8	24	42	66	63.6
Navicular	12.3	30	27	57	47.4
Lesser multangular	14.8	37	29	66	43.9
Distal ulna	15.3	5	18	23	78.3

<sup>1</sup> Bones are arranged in order of appearance of centers of ossification in the left hand; taken from data listed in table 2, Pyle and Sontag ('43).

relation coefficients obtained and the levels of significance ( $p$ ) are shown in table 4.

Frequency of bilateral asymmetry correlates equally well with order of appearance of the centers of ossification and with the standard deviations for onset of ossification of the individual bones, as would be expected, since the order of appearance of the centers and the standard deviations are highly correlated.

*Sex differences in the maturational asymmetry of the hands.* The mean percentages of asymmetry of the 15 bones for which data are available for both sexes is 32.63% for boys and

TABLE 4

*Intercorrelations ( $\rho$ ) and levels of probability ( $p$ ) for the variables, order of appearance of the centers of ossification, standard deviations of onset of ossification, and frequency of bilateral asymmetry*

VARIABLES CORRELATED		BOYS		GIRLS	
		$\rho$	$p$	$\rho$	$p$
Order of appearance	SD	.893	.001	.917	.001
Order of appearance	Bilateral asymmetry	.754	.001	.704	.01
SD	Bilateral asymmetry	.664	.01	.719	.01

30.21% for girls. A test of the significance of the difference for matched groups (Edwards, '50) indicates that there is no significant sex difference in total percentage of asymmetry during the first three stages of skeletal maturation of the hand and wrist ( $t = .873$ ;  $p = .40$ ). The rank order correlation coefficient further demonstrates great comparability in the relative degree of asymmetry of the individual bones in boys and girls ( $\rho = .789$ ;  $p < .01$ ).

*Right-hand versus left-hand advancement in skeletal maturation.* Some authors have suggested that one hand may tend to be more advanced in skeletal maturation, on the average, than the other. Schinz, Baensch, Friedl and Uehlinger ('51)



contend that where a bilateral difference in stage of ossification is present, the left wrist is generally more advanced than the right. Torgersen ('51) is also of the opinion that ossification of the bones of the wrist proceeds more rapidly on the left side. Menees and Holly ('32), however, report that where centers of ossification appear asymmetrically, they tended to be evident earliest in the right hand. Elgenmark's ('46) report contains still a third point of view, namely, that in the event of bilateral asymmetry, either hand may be maturationally in advance of the other. None of these studies, however, presents statistical material comprising a test of the significance of the bilateral differences reported.

In the present study, 286 instances of bilateral asymmetry were observed in the male series and 207 in the female series. For the boys, the right hand was found to be more advanced 147 times and the left 139 times; for the girls, the right hand was more advanced in 96 instances and the left in 111. Application of a  $t$  test for matched groups indicates that in neither sex is one hand significantly advanced maturationally over the other (boys:  $t = .393$ ,  $p = .70$ ; girls:  $t = 1.17$ ,  $p = .30$ ). The rank order correlation coefficients (boys:  $\rho = .80$ ,  $p = < .001$ ; girls:  $\rho = .85$ ,  $p = < .001$ ) indicate that the same bones are involved when either the right or the left hand is maturationally more advanced; in other words, specific centers of ossification do not exhibit different bilateral trends.

Unfortunately, data concerning handedness were not available for the series here reported. Therefore the suggestion put forth by Flecker ('32), Menees and Holly ('32), and Torgersen ('51), that skeletal advancement of one hand is related to function, could not be tested.

#### DISCUSSION

The analysis of bilateral asymmetries in maturation occurring in a normal population tests certain assumptions which are implicit in the clinical use of normative standards (Flory, '36; Todd, '37; Greulich and Pyle, '50) derived from the study of only one side of the body. For example, is the

ossification of the skeleton of one hand representative of development bilaterally? Or, put in operational terms, is it necessary to assess roentgenograms of both hands in order to arrive at a correct estimate of the developmental status of the skeleton? And, assuming that bilateral differences in rate of appearance of centers of ossification are noted, what is the significance of this fact for the clinical interpretation of adequacy of development?

The data presented in this paper suggest possible answers to these questions. First, considering the total occurrence of bilateral asymmetries, neither hand was found to be significantly advanced in development over the other. In general, the most advanced center of a pair of asymmetrical bones may appear in either hand, since the centers of ossification do not exhibit different bilateral trends. Second, bilateral asymmetry shows a positive relationship to the order of appearance and the variability in onset of ossification reported for the centers in the left hand. Worth noting in this connection is the interesting parallel in the carpal bones of great variability in onset of ossification and great degree of bilateral asymmetry, in contrast to the markedly lesser degree of variability and bilateral asymmetry taking place in the epiphyses of the hand. These findings suggest that the degree of bilateral asymmetry which does occur in a population of normal children is a function of the variability in the time of initiation of the ossification process. Accordingly, bilateral asymmetry, at least during the early stages of maturation, does not appear to be a separate phenomenon requiring separate treatment.

The conclusion that bilateral asymmetry is an extension of the variability in rate of maturation of the bones within one hand emphasizes the importance, for clinical application, of further investigation of the factors influencing variation in ossification. The present standards provide a basis for determining whether a child is progressing rapidly or slowly or is approximating the average of the population in general rate of skeletal maturation. However, given a roentgenogram

in which the individual bones show a wide spread of skeletal ages, or in which the appearance of missing centers is long overdue, the clinician is confronted with alternative interpretations concerning the cause and significance of the developmental inconsistency. Todd ('37), Francis and Werle ('39), Francis ('40), Pyle et al. ('48), and Mann et al. ('48) have stressed the importance of metabolic disturbances, disease, and chronic nutritional deficiency in producing maturational asymmetry. On the other hand, Pryor ('07), Sontag and Lipford ('43), Reynolds ('43), Robinow ('42), and Garn, among others, have emphasized the role of hereditary variation in creating diverse ossification patterns. Although the latter interpretation does not eliminate the former as a factor, it brings into serious question the status of each of these factors as sole determinants.

The problem facing the clinician, then, is to distinguish between hereditary variation and pathological aberration in the absence of specific diagnostic criteria. The present writers have encountered, in the Merrill-Palmer Longitudinal Series, instances of delayed appearance of ossification centers and sufficiently slow maturation of others to warrant an assumption of systemic disturbance were it not for the fact that the same pattern in considerable detail appeared in a sibling several years later.

Clinical application, however, demands immediacy of judgment. The alternative interpretations concerning the meaning of developmental skeletal asymmetries do not per se afford criteria of discrimination. The need for such criteria to complement the use of present standards of skeletal maturation suggests that more research might profitably be directed toward a determination of the mechanisms controlling the processes of ossification at the histological level. Several studies have shown, for example, that there is greater variability in the time of onset of ossification in the carpal bones than in the epiphyses. What is now needed is an explanation of the anatomical factors responsible for this occurrence.

## SUMMARY

Bilateral asymmetries occurring during the first three stages of skeletal maturation of the hand and wrist (as defined by Greulich and Pyle, '50) were analyzed. The bilateral differences in maturational status of each of the bones were determined through comparisons of radiographs of right and left hands of the same children.

*Findings*

1. In both sexes the carpal bones, taken as a group, show a considerably higher average percentage of asymmetry than the average for the epiphyses.

2. Frequency of bilateral asymmetry in the individual bones correlates significantly and equally well with the order of appearance of the centers of ossification and with the standard deviations for onset of ossification of the individual bones.

3. There is no significant sex difference in total percentage of asymmetry during the first three stages of skeletal maturation of the hand and wrist.

4. There is great comparability in the relative degree of asymmetry of the individual bones in boys and girls.

5. For both sexes, considering the total occurrence of asymmetries, neither hand was found to be significantly advanced maturationally over the other.

6. In those instances in which either the right or left hand is advanced maturationally, the same bones are involved; in other words, specific centers of ossification do not exhibit different bilateral trends.

7. The conclusion is drawn that the degree of bilateral asymmetry which does occur in a population of normal children is a function of the variability in the initiation time of the ossification process.

8. The need for establishing criteria, for clinical use, to discriminate between normal hereditary variation and pathological aberration is discussed.



## ACKNOWLEDGMENTS

The authors wish to acknowledge their indebtedness to colleagues at The Merrill-Palmer School, especially to Dr. S. Idell Pyle for suggesting the present analysis and for many profitable discussions on the subject of skeletal maturation; to Dr. Harriet J. Kelly for statistical advice and for a critical reading of the manuscript; and to Miss Dorothy L. Tyler, Editor of Publications, for preparing the manuscript for publication.

## LITERATURE CITED

- ACHESON, R. M. 1952 Radiographs of hand as index of skeletal maturity in infants. *Arch. Dis. Child.*, *27*: 382-385.
- 1954 A method of assessing skeletal maturity from radiographs: a report from the Oxford Child Health Survey. *J. Anat.*, London, *88*: 498-508.
- ALLEN, B. 1926 An X-ray study of the development of the ossification centers of the skeletal system. *Radiology*, *7*: 398-409.
- BALDWIN, B. T. 1921 The physical growth of children from birth to maturity. *Univ. Iowa Stud. Child Welf.*, *1*, no. 1, first series no. 50. Iowa City.
- BALDWIN, B. T., LAURA M. BUSBY AND HELEN V. GARSIDE 1928 Anatomic growth of children: a study of some bones of the hand, wrist and lower forearm by means of roentgenograms. *Univ. Iowa Stud. Child Welf.*, *4*, no 1. Iowa City.
- BARDEEN, C. R. 1921 The relation of ossification to physiological development. *J. Radiol.*, *2*: 1-8.
- BOROVANSKY, L., AND O. HNEVKOVSKY 1929 The growth of the body and the process of ossification in Prague boys from 4 years to 19 years. *Anthropologie*, Prague, *7*: 169-208.
- EDWARDS, A. L. 1950 *Experimental Design in Psychological Research*. New York, Rinehart and Co.
- ELGENMARK, O. 1946 The normal development of ossific centers during infancy and childhood; clinical, roentgenologic and statistical study. *Acta paediat.*, Stockholm, (Sup. I), *33*: 1-79.
- FLECKER, H. 1932 Roentgenographic observation of times of appearance of epiphyses and their fusion with the diaphyses. *J. Anat.*, *67*: 118-164.
- 1942 Time of appearance and fusion of ossification centers as observed by roentgenographic methods. *Am. J. Roentgen.*, *47*: 97-159.
- FLORY, C. D. 1936 Osseous development in the hand as an index of skeletal development. *Monog. Soc. Res. Child Developm.*, *1*, no. 3.
- FRANCIS, C. C., AND P. P. WERLE 1939 The appearance of ossification centers from birth to five years. *Am. J. Phys. Anthropol.*, *24*: 273-299.
- FRANCIS, C. C. 1940 Factors influencing appearance of centers of ossification during early childhood. *Am. J. Dis. Child.*, *59*: 1006-1012.



- GARN, S. M. Aberrant genetically-determined patterns of carpal ossification. (In preparation for Clinical Orthopaedics.)
- GREULICH, W. W., AND S. IDELL PYLE 1950 Radiographic Atlas of Skeletal Development of the Hand and Wrist. Stanford University Press.
- KÖHLER, A. 1924 Grenzen des Normalen und Anfänge des Pathologischen in Röntgenbilde. 4th edition. Hamburg, L. Gräfe und Sillem.
- LONG, E., AND E. W. CALDWELL 1911 Some investigations concerning the relation between carpal ossification and physical and mental development. *Am. J. Dis. Child.*, 1: 113-138.
- MANN, A. W., S. DREIZEN, S. IDELL PYLE AND T. D. SPIES 1948 The red graph and the Wetzel grid as methods of determining the symmetry of status and progress during growth. *J. Pediat.*, 32: 137-150.
- MENEES, T. O., AND L. E. HOLLY 1932 The ossification in the extremities of the new-born. *Am. J. Roentgen.*, 28: 389-390.
- NOBACK, C. R., AND G. G. ROBERTSON 1951 Sequences of appearance of ossification centers in the human skeleton during the first five prenatal months. *Am. J. Anat.*, 89: 1-28.
- PRYOR, J. W. 1907 Hereditary nature of variation in ossification of bones. *Anat. Rec.*, 4: 84-88.
- 1916 Some observations of the ossification of the bones of the hand. *Bull. Univ. Kentucky*, 8, no. 11.
- PYLE, IDELL, AND L. W. SONTAG 1943 Variability in onset of ossification in epiphyses and short bones of the extremities. *Am. J. Roentgen.*, 49: 795-798.
- PYLE, S. IDELL, A. W. MANN, S. DREIZEN, HARRIET J. KELLY, ICIE G. MACY, AND T. D. SPIES 1948 A substitute for skeletal age (Todd) for clinical use: the red graph method. *J. Pediat.*, 32: 125-136.
- REYNOLDS, E. L. 1943 Degree of kinship and pattern of ossification. *Am. J. Phys. Anthropol.*, n.s. 1: 405-416.
- ROBINOW, M. 1942 Appearance of ossification centers. *Am. J. Dis. Child.*, 64: 229-236.
- SAWTELL, RUTH O. 1929 Ossification and growth of children from one to eight years of age. *Am. J. Dis. Child.*, 37: 61-87.
- SCHINZ, H. R., W. E. BAENSCH, E. FRIEDL AND E. UEHLINGER 1951 Roentgen-Diagnostics. Vol. I. New York, Grune and Stratton.
- SONTAG, L. W., AND JANET LIPFORD 1943 The effect of illness and other factors on the appearance pattern of skeletal epiphyses. *J. Pediat.*, 23: 391-409.
- TODD, T. W. 1937 Atlas of Skeletal Maturation (Hand). St. Louis, C. V. Mosby Co.
- TORGENSEN, J. 1951 Asymmetry and skeletal maturation. *Acta Radiol.*, Stockholm, 36: 521-523.
- WATSON, E. H., AND G. H. LOWREY 1954 Growth and Development of Children. 2nd edition. Chicago, The Year Book Publishers, Inc.

# MUSCLE GROWTH AND FUNCTION IN RELATION TO SKELETAL MORPHOLOGY <sup>1</sup>

J. H. SCOTT

*Anatomy Department, Queen's University, Belfast, Ireland*

NINE FIGURES

## INTRODUCTION

It is well known that the form of certain parts of the skeleton depend for their full development on the degree of activity of the attached muscles. In the case of complex skeletal structures such as the cranium, facial skeleton and pelvis, other factors are also concerned in form determination, and considerable uncertainty exists regarding the role of muscle action in determining the morphology of these parts. Furthermore, there exists a complex but fascinating group of problems in relation to the possible mechanisms involved in those alterations in skeletal form, which differentiate closely related species, and which reflect changes in the pattern of their neuro-muscular behavior. In this article it is proposed to gather together some of the scattered information from various compartments of biological knowledge in an attempt to construct a working hypothesis of the developmental and functional interrelationships which may exist between the neuro-muscular and skeletal systems within an organism.

## THE DEVELOPMENT AND GROWTH OF MUSCLE

Differentiation of striped muscle commences in the human embryo at about the seventh week and the typical structure of the muscle fibres is reached by the twenty-second week

<sup>1</sup> A grant from the Wenner-Gren Foundation for Anthropological Research covers the cost of printing this article.

(Hewer, '27). The developing muscle fibres obtain nerve connections soon after their first differentiation (eighth week) (Windle and Fitzgerald, '37), but the maturation of the motor end plates and the commencement of normal functional activity does not occur until the end of the seventh month and is not complete in the limbs, especially in the foot and leg, until after birth (Hewer, '35). Sensory nerve endings (muscle spindles) develop and differentiate before the motor end plates (Dickson, '40), and reflex muscle contractions resulting from stimulation of the surface of the body can take place while the motor end plates are still quite immature.

Harrison ('04) showed that the initial differentiation of muscle fibres can take place without any nerve connections, but more recently Eastlick ('43) has shown that full differentiation of muscle tissue and the arrangement of muscle fibres into bundles occurs only in the presence of a connection between the developing muscle and its nerve. If there is no development of the nerve-muscle connection, the muscle fibres do not develop beyond a certain stage, and they later undergo degeneration.

The developing muscles at first are independent of the skeletal elements, to which they later gain attachment. If one or more of the skeletal elements to which a muscle normally gains attachment is absent, the development of the muscle continues. Hall ('50) showed that in larval amphibians such a muscle as the levator mandibulae may be well developed in the absence of its insertion, the mandible, the muscle terminating in loose mesenchyme in place of its normal attachment. He also produced evidence that early differentiation of the muscles of mastication is related to a proper development of the adjacent cartilage elements, such as the palatoquadrate bar. In the mammalian skull the muscles of mastication first develop in relation to Meckel's cartilage and later gain attachment to the mandible (Edgeworth, '35; Scott, '51).

Conditions such as clubfoot may be due to the developing muscles becoming attached to the skeleton in an abnormal

position (Stewart, '51), to degeneration and replacement by fibrous tissue of part of the muscle tissue (Bechtol and Mossman, '50), or to failure of proper correlation in growth of bone and muscle (Middleton, '34). Areas of degeneration in developing muscle may be associated with nerve lesions, as it is known that each nerve fibre in a motor nerve to a muscle supplies a certain number of muscle fibres. Degeneration of an individual nerve fibre will result in the degeneration of a number of muscle fibres.

During early foetal life skeletal muscle grows by division of developing fibres or by the further differentiation of muscle-forming cells, but it is generally believed that after the fourth month of foetal life in man growth of muscle tissue is by hypertrophy of individual fibres, which increase in both length and width (Bardeen, '06). Muscle fibres of the tail of the tadpole increase in diameter two or three times, or even more, during the growth period from the time of hatching to metamorphosis. Growth by differentiation of new fibres is much more limited (Speidel, '38). Lockhart and Brandt ('38) showed that in the sartorius muscle of a human foetus a single fibre ran the whole length of the muscle and was at that time some 5 cm long. They believe that in the adult the muscle fibres still run the whole length of the muscle, which is more than 50 cm in length.

Between one year of age and adult life, the human masseter muscle increases in thickness about 4 times and in cross-section area about 8 times. This increase is produced in part by an increase in the fibrous tissue and tendon substance separating and giving attachment to the muscle bundles, but is caused largely by an increase in size of the individual muscle fibres. In the adult, each fibre in cross section is two or three times as thick as in the child at one year of age. Furthermore, in the child there is a greater variation between the sizes of the individual fibres, some fibres still retaining the foetal dimensions. During childhood it would appear that the following processes contribute to the growth of muscle.

1. There is a relatively great increase in size on the part of those fibres that are still of foetal size in early childhood. This growth probably is related to a fuller maturation of the nerve-muscle connections.

2. There is an increase in size of the larger fibres of the child's muscle up to adult dimensions, but even in the adult some fibres are less developed than others. These probably form a functional reserve of muscle substance to meet the demands of greater masticatory function.

3. There is an increase in the bulk of the fibrous tissue between and around the muscle bundles.

Lorrain Smith ('32) wrote of skeletal muscle: "... the consideration of muscle is that of a tissue fixed in early life with no power of growth by cell multiplication. The increase in bulk is a function of activity. When a muscle has less work it atrophies. When it has more work it hypertrophies. The size of a muscle is a register of the work it has to do."

Haines ('32) believes that muscle fibres grow along their whole length in response to traction set up by the growth of the bones to which the muscle is attached and that unwanted muscle substance (that is, a length of muscle fibre over and above what is required to produce the normal movements at the joints at which the muscle acts) is converted into tendon. Speidel ('38) also holds that tendon fibres are muscle cell derivatives. Haines admits, however, that traction will not account for muscle migration, as illustrated by the growth of the temporal muscle.

It should be remembered, however, that the growth in width of a muscle is in some ways a different process than growth in length. The increased area of attachment of the origin of the temporal muscle and of the insertion of the masseter is directly related to the growth in width of the muscle substance and not to any great extent to growth in length of individual fibres. The insertion of the temporal muscle and of the external pterygoid, on the other hand, is largely through tendon and there is a much less extensive increase in the



area of attachment. The migration of the temporal muscle is due essentially to an increase in the area of its origin related to the growth in width of the individual muscle fibres, each of which is attached to bone. In its insertion most of the muscle fibres are attached, not directly to the mandible, but to a large tendinous area within the substance of the muscle (fig. 1), and it is through this tendon that the muscle gains its more limited attachment to the coronoid process.

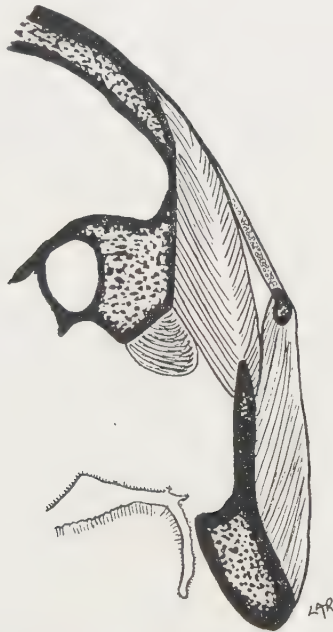


Fig. 1 The origin and insertion of the temporal muscle.

Growth in length of the muscles of mastication, whether by increase in size of individual muscle fibres or increase in tendinous substance, is related to the growth of two cartilaginous areas of the skull (fig. 2). In the case of the masseter, internal pterygoid, and vertical fibres of the temporal muscle, the cartilage of the mandibular condyle continues to separate the muscle origins from the muscle insertions. In the case of the external pterygoid and the horizontal fibres

of the temporal, origin and insertion are separated by the growth of the cartilage of the cranial base (sphenoccipital synchondrosis). It is the continual growth of this cartilage that makes room for the developing muscles of mastication between the vertebral column and the back of the facial skeleton (Keith, '10). Space also is provided for the muscles

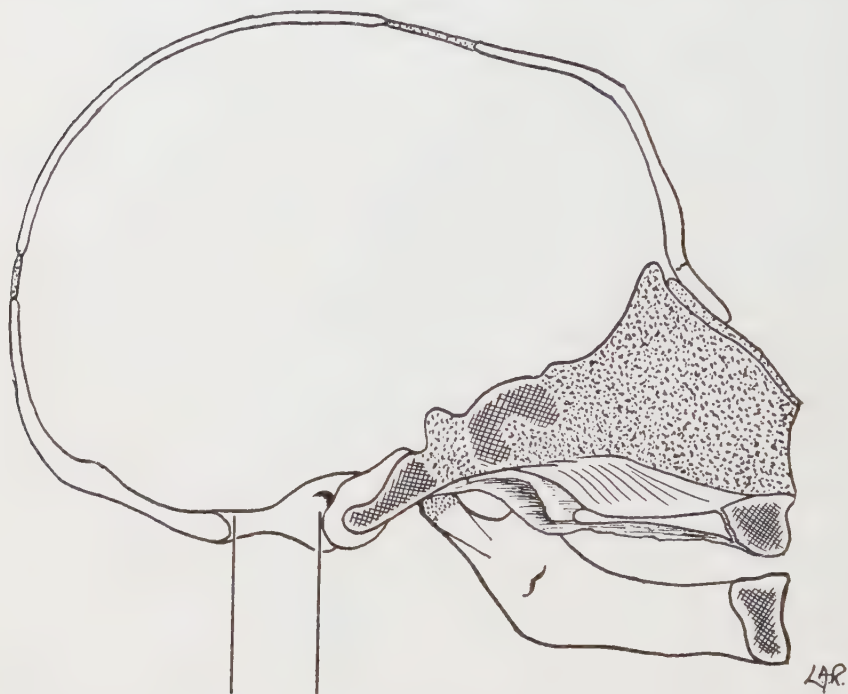


Fig. 2 Cranial base of a human fetus to show position of cartilage growth areas.

of mastication by the lateral growth of the zygomatic arches (fig. 3), which is brought about by a combined process of bone absorption, deposition and suture growth (Brash, '34). Friel ('26) has published results showing the correlation between the power of the bite, as measured by a dynamometer inserted between the first permanent molars, and the sitting height. The results give an indication of the correlation

between the growth of the muscles and the development of the dentition. From about 6 years to about 10 years of age, the muscles develop at a steady rate as indicated by the bite pressure. Between 10 years and 15 years, there is but little further development, while after 15 years the development

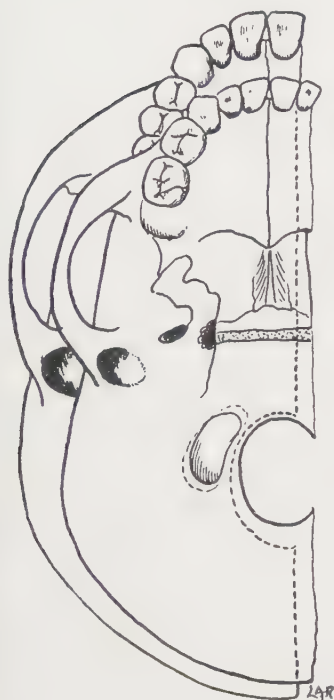


Figure 3



Figure 4

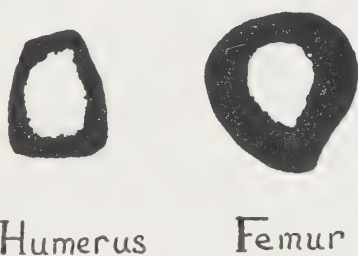


Figure 5

Fig. 3 Skull of child and adult to show growth in zygomatic region.

Fig. 4 Cross sections of human humerus at 10 years, adult, and old age.

Fig. 5 Cross sections of human humerus and femur (adult).

of the muscles is more rapid than between 6 and 10 years. The muscles develop most rapidly after puberty in association with the replacement of the deciduous teeth by the permanent dentition, which is complete by the end of the twelfth year, and the eruption of the second and third permanent molars.

MUSCLE DEVELOPMENT AND THE DEVELOPMENT  
OF CORTICAL BONE

Figure 4 shows the appearance in cross section of a humerus of a child of 10 years, of an adult, and of an old person. It will be noticed that the thickness of the cortical bone is considerably greater in the case of the adult. This increase in the amount of cortical substance, built up of tightly packed Haversian canal systems, is related to the greater muscular development of the adult. In old age, with atrophy of the muscles, the cortical substance is reduced in amount and the bone becomes thinner and more liable to fracture. Figure 5 shows the appearance, as seen in cross section, of a humerus and femur from an adult. The thigh bone shows the thicker cortex. The bones of the lower limb not only have to act as levers for muscle movement, but they also have to transmit the weight of the body to the feet, both while at rest (standing), and during locomotion (table 1). As a rule, the right humerus and the left femur are thicker and also longer than the opposite bones, as the muscles of the right arm are usually better developed and the body weight transmitted more to the left leg (Martin, '28).

TABLE 1

	<i>mm</i>
Thickness of humerus (10 years)	3
Thickness of humerus (adult)	5
Thickness of humerus (old age)	2
Thickness of femur (adult)	8

Hrdlicka ('32) gives information on the dimensions of the left and right humerus in various races. Irish males, who were mostly manual labourers, showed the strongest humeri; while American Indians, who do but little manual work, had the least developed bones. The mean value for the mid shaft diameter of the right and left bones was 21.9 mm and 20.7 mm for the Irish series, and 19.5 and 18.7 mm for the Indian series. Racial or genetic factors are probably of some importance as Italian labourers have less robust bones than the Irish,

Germans or native Americans, but Hrdlicka considers that the differences are for the most part probably functional. The difference between the bones of the left and right sides is probably entirely an expression of differences in degree of use.

Schultz ('53) studied the relative thickness of the limb bones in a large number of primates. He found an increase in thickness with increase in body weight. In man with the acquisition of the upright posture the relative thickness of the bones of the lower limb reach a maximum. At the same time there has occurred some reduction in the relative thickness of the bones of the upper limb. There is also in man the greatest proportionate thickening of the vertebrae especially in the lumbar region.

In muscular paralysis, especially if the onset of the paralysis occurred during the growth period, the limb bones are deficient in both length and thickness. Humphry (1862) observed that the thinness of the bones in paralysis, in other words, the deficiency of lateral growth, is a more marked and constant feature, and affords a better example of the relation between the growth of the bones and muscular action, than the deficiency in length. Tower ('37) rendered the muscles of the hind limbs of puppies inactive by section of the posterior roots and the spinal cord in the lumbosacral region. The muscles underwent atrophy and the bones were deficient in thickness. Structures for the attachment of muscles were poorly developed, but growth in length of the bones was not affected. Gillespie ('54) cut the anterior and posterior nerve roots to the limb muscles in kittens. He obtained a significant reduction in the cortical thickness of the limb bones, but little change in growth in length; epiphyseal growth was not affected to nearly the same extent as appositional growth.

Figure 6 shows the appearance of the body of the mandible as seen in cross section in a series of pigs of different ages. In each case the section was cut immediately in front of the tooth which occupied the back of the dental arch. It will be



seen that the thickness of the cortical bone increases with age and with the development of the dentition (table 2).

In table 2 is also shown the approximate area for the insertion of the masseter muscle. It will be noticed that there is a contemporaneous development of tooth eruption, thickening of cortical bone, and muscle development, which suggests that there is a general correlation between the growth of the muscles of mastication, the development of the dentition, and the strength of the mandible.



Fig. 6 Cross sections of pig mandibles at different ages.

There are, however, factors other than the demands of function and muscle development in the determination of the thickness of cortical bone, as is shown in the development of the bones of the manatee (Fawcett, '42). In this animal there is no absorption of the cortical bone from within to form the characteristic medullary cavity while the periosteum continues to deposit bone on the external surfaces. It must

be remembered that the proper development of skeletal elements in relation to the demands of mechanical function is a matter of proper balance between bone deposition and bone absorption. Bone absorption, in turn, is related to such diverse factors as the growth of air sinuses (as in the skull of the pig and elephant and the limb bones of birds) (Bremer, '40), the formation of bone marrow, the storage of calcium salts in relation to the formation of egg shells in birds (Bloom, Bloom and McLean, '41), and the growth of antlers in deer (Meister, '56), so that bone deposition must always be adequate to allow for these non-mechanical factors in bone morphology.

TABLE 2

AGE	LAST TOOTH ERUPTED	THICKNESS OF CORTICAL BONE	AREA OF INSERTION OF MASSETER
		(mm)	(cm <sup>2</sup> )
5 weeks	Third deciduous molar	2	10
3 months	Third deciduous molar	3	25
6 months	First permanent molar	3	32
1 year	Second permanent molar	3.5	..
Adult	Third permanent molar	4	56

## BONE GROWTH AND BONE DEFORMITY

While the thickness and internal structure of bone is related to its use, the growth of bone, especially in so far as this is the result of cartilage growth, is to a considerable extent independent of use. Growing bone, however, is susceptible to deformation resulting from abnormal forces acting upon it, provided these forces are continuous. Appleton ('34) sectioned some of the muscles inserted into the femur in rabbits. As a consequence of the resulting abnormal posture, changes in form took place in all the bony elements of the limb. The changes occurred in the regions of bone growth at the metaphyseal region, and continued to increase as growth continued. No changes occurred if adult animals were used. In the

post-natal growing skull corresponding metaphyseal regions are present in relation to the growth cartilages of the cranial base, mandibular condyles and nasal septum (fig. 2). Bone normally undergoes changes in form during growth. Abnormal form, therefore, can be produced by abnormal forces acting upon normal bone during its growth. In "postural" scoliosis, however, no deformity of bone structure occurs. The vertebral column, with its numerous intervertebral discs, is built to resist deformity. Moreover, in postural scoliosis the deforming force is not constant as in Appleton's muscle-cutting experiments.

Skull deformity can be produced by the removal or paralysis of muscles (Horowitz and Shapiro, '55), and by the use of cradle boards in infancy (Hrdlicka, '35; Imbelloni, '50). These deformities are not produced by the pressure exerted by the apparatus itself but by a change in the direction of growth on the part of the growing brain or growth regulating cartilages. Another category of cranial deformities are the result of growth failure on the part of the growth regulating cartilages of the cranial base, nasal septum and mandibular condyles. These include achondroplasia, Mongolism, and hypotelorism (Brash, '56).

If the bone structure is itself abnormal, as in rickets or Paget's disease, then normal forces will produce abnormalities of bone form, and again the chief sites of deformation are situated at the region of most active growth.

#### MUSCLE DEVELOPMENT AND THE FORM OF THE SCAPULA

Wolffson ('50) carried out experiments to determine the changes occurring in the form of the scapula following removal of the attached muscles or their paralysis following nerve section. She found a considerable reduction in the spinous process, the supraspinatus and infraspinatus fossa and of the vertebral border. These regions of the scapula are associated with muscle attachment and correspond in their morphological behaviour with the coronoid process and angle of the mandible.

## MUSCLE DEVELOPMENT AND THE FORM OF THE SKULL

The form of the lower jaw can be analyzed into more than one element. If the muscles of mastication atrophy as the result of disuse, injury, or old age, the shape of certain parts of the bone changes. Washburn ('47) removed the temporal muscle in one-day old rats. Three to 5 months later the coronoid process of the mandible on the operated side was almost entirely absent. In old age both the coronoid process and angle of the mandible show loss of bone substance. In a similar manner, if the teeth are shed or extracted the alveolar bone becomes resorbed. The total length of the mandible from condyles to chin, however, is not affected as a result of these local changes in form. Therefore, we can analyze the mandible into a basal element, and alveolar element, and muscular processes (Symons, '51; Washburn, '51). While the structure of the bone changes throughout with changes in the degree of use, the associated changes in form are much more localized and are closely related to the developmental history of the bone (Fawcett, '24; Low, '10).

The Eskimos have developed the muscles of mastication to a greater degree than most human races. The characteristic features of the skull related to this functional use of the muscles have been described by Cameron ('23), Hrdlicka ('40), Pedersen ('49), and Collins ('50) and include:

1. The temporal ridges are well marked, are situated well up on the sides of the cranium, and are associated with the massive temporal muscles.

2. The zygomatic arches are well developed to give origin to the powerful masseter muscles and also in relation to the forces of mastication acting through the arches as elements of the facial buttress system (Weinmann and Sicher, '47). They project markedly in the lateral direction to allow of a large space between them and the side of the skull for the temporal muscles passing from their origin to the coronoid processes of the mandible.

3. The lateral pterygoid plates are exceptionally wide and the maxillary tuberosities are well developed in relation to the origin of the pterygoid muscles.

4. In the mandible the angular region is well developed with eversion of the outer border; the coronoid processes are strongly developed and the ramus is wide in relation to the height. The bigonial width of the mandible is greater than in other races.

5. The glenoid fossae are shallow, with poor development of the eminentia articularis in association with the extensive side-to-side movements and use of the incisors in chewing tough food and softening hides.

6. Palatal and mandibular tori are frequently present and they are well developed.

Male Eskimos 14 years old and over can produce an average bite pressure of between 250 and 300 pounds in the molar region, with a maximum of 348 pounds, in one series of investigations (Vaugh, '37). The best result obtained by Friel ('26) in a 15-year old Irish boy was 170 pounds.

It should be noted, however, that the masticatory environment is in itself not sufficient to account for all the characteristic features of Eskimo cranio-facial morphology. The Lapps (Selmer-Olsen, '49) live under conditions very similar to those of the Eskimos and are characterized by a delicate cranio-facial skeleton. In Africa we have the same contrast between the Congo negroes and the pygmies (Maly and Matiegka, '38). It would appear that the ability of the cranio-facial skeleton to respond to the functional demands of increased masticatory activity is to a large extent determined by a genetically controlled plasticity of bone. It is probable that the Eskimo has an inherent tendency towards the development of massive bony structure which is fully expressed in his primitive environment and which is not expressed under the conditions of modern civilization. Furthermore, the Lapps have smaller teeth. The combined anteroposterior length of the lower permanent molars is on the average 31.3 mm as compared with an average of 34.6 mm in the



Eskimo. The Lapp has therefore less need of alveolar bone as it is the size of the teeth which determines the minimum size of the alveolar processes.

Cameron ('23), Thomson ('03) and others believed that the muscles of mastication, especially the temporal muscles, have an important role in determining the form of the cranial vault, while Trotter ('41) put forward the theory that the freeing of the skull from accessory functions, especially those associated with massive neck and masticatory muscles, was an important factor in the evolution of the human brain. Weidenreich ('40), however, provides convincing evidence that these mechanical influences only affect the development of the superstructures, but not the form and development of the cranium itself, and still less the brain. Abbie ('47) stated that there is no correlation between the form of the cranium and the size of the jaws. It would appear that the degree of development of the muscles of mastication and of the dentition with which such development is related, can modify the form of the skull through certain structural changes, such as the development of sagittal crests, the size of the mandibular ramus and lateral pterygoid plates, the thickness of the cortical bone, and therefore the robustness and size of the body of the mandible and the development of the facial buttress systems. However, the development of the muscles does not determine the total form of the skull and especially such regions as the cranial base, the basal element of the mandible, the orbital cavities, and the nasal cavities. Quite independently of muscle function and development, the growth of the brain, eyeballs, and nasal cavities and the growth of the cartilage of the cranial base, mandibular condyle, and nasal septum play an important part in contributing to the development and form of the skull. Harris ('26) wrote: "As for the skull crests (in the Gorilla), so for endocranial skull form; there is not only a 'muscle' factor, a 'dentition' factor, a 'face' factor and a 'brain' factor, but there is also a 'skull' factor which is at present too complex to be analysed in terms of race alone." Townsley

('48) produced evidence that not only may the structure of bone be associated with function in ontological development, but that mechanically determined structures may present themselves as hereditary features in young bones which, in the particular individual, have been protected experimentally from the stresses and strains of muscle pull and weight bearing. This hereditarily determined structure of bone may be related to increased muscular coordination and differentiation in association with the phylogenetic development in complexity on the part of the central nervous system (Wright, '34).

Krahle and Evans ('45), in their study of humeral torsion in man, came to the conclusion that the torsion of this bone is the result of the interaction of a primary hereditary torsion upon which is superimposed a secondary ontogenetic torsion produced by function.

Torus palatinus is an interesting structure which has been studied by many investigators. It is a mid line thickening of the hard palate composed of a covering of cortical bone with intervening spongy bone. It is most common in Eskimos, American Indians and Mongolians, and least frequent among American Negroes. It is rare in primates other than man. It may show itself in foetal life and increases in size from birth to maturity and then ceases to grow with age. It has been ascribed to excessive development of the masticatory mechanism (Hooton, '18), irritation of the mucous membrane (van den Broek, '45), and to hereditary constitution (Woo, '50).

It would appear that torus palatinus like torus mandibularis (Moorrees et al., '52) and parietal torus is a morphological feature inherent in human heredity but which requires for its development an environment in which there is a heavy use of the masticatory apparatus. As with torsion of the limb bones, the development of mandibular and palatal tori open up a wide field of problems related to the mechanism or mechanisms whereby the effects of function in the individual become incorporated in the hereditary constitution of the species. Here it is only possible to make the suggestion that

a number of morphological features may exist in a species in a latent form and only develop with the acquisition of specific functional behaviour. This latent variability of a species would, of course, greatly extend the limits of a given species, and certain categories now defined as separate but closely related species may be the consequence of the expression of this latent variability.

The relation of muscle function to the structure and form of the skull may be summed up here as follows:

1. In the skull certain elements of the adult form are entirely independent of muscle growth and action, but are related to the growth of other organs and tissues.

2. Certain elements of structure and form are related to muscle function through phylogenetic development and develop in a particular individual to a certain degree independently of the development or action of the muscles of that individual.

3. Certain other elements of structure and form, chiefly concerned with actual size or thickness or strength of parts, depend for their full development upon the degree of muscular function in the individual.

We now will consider further evidence in support of these conclusions.

#### THE TEMPORAL MUSCLES AND CRANIAL FORM

Riesenfeld ('55) gives information on cases in which the temporal lines of each side closely approach one another on the cranial vault in human skulls. He points out that in these skulls, as in those of microcephalic idiots, the large area of attachment of the muscles relative to cranial size bears little if any relationship to skull form. In the skulls studied some were dolichocephalic, some mesocephalic, and others brachycephalic. Skulls with strong development of the temporal muscles however often show the presence of a parietal torus. This structure would appear to belong to the same category as palatal and mandibular tori and bear

some relationship to the development of powerful muscles of mastication.

Harris ('26) has shown that in gorillas in spite of the developmental sagittal and occipital crests and the almost complete covering of the cranium by the temporal and neck muscles, there is a wide range of variation in the form of the cranial cavity itself. The endocranial breadth/length index varies from 72.1 to 86.8. There is need for more work on the variability of growth of different parts of the cerebral hemispheres. During foetal life and early childhood, the brain is not growing within a rigid skeletal capsule but rather within its dural membrane to the surface of which the delicate cranial bones are attached (Moss, '54). It is probable that cranial form is determined largely by the pattern of growth of the brain itself and this is largely determined before the muscles have reached their full functional development.

#### MUSCLE MIGRATION

Jager and Moll ('51) investigated the development of the triceps surae muscle (gastrocnemius and soleus) in man. The muscle develops on the lateral side of the leg. The adult muscles reach their definitive form and position by a combined process of differential development and migration. In phylogeny the change from the lateral position, which is typical of tetrapods, to the posterior position of human anatomy appears to be correlated with the acquisition of the upright posture. Schauder ('26) showed that the pronator quadratus is present in the embryo of the horse although absent in the adult, and Holmgren ('40) has described a proximo-distal migration of the human pronator quadratus.

The process of muscle migration may consist of the extension of its area of attachment as in the temporal muscle or in a change in position with the acquisition of new attachments and a new function. Associated with the process of muscle migration there is often a marked change in the morphology of the adjacent skeleton. Washburn ('50) has made the interest-



ing suggestion that such a process is one of the factors responsible for the difference in form in the pelvis of the anthropoid apes and man.

THE CORRELATION BETWEEN THE GROWTH OF THE TEMPORAL  
MUSCLE AND THE DEVELOPMENT OF THE DENTITION

Keith ('10) showed that in the male gorilla the temporal ridge, marking the upper limit of attachment of the temporal muscle, reaches about 10 mm above the lower border of the

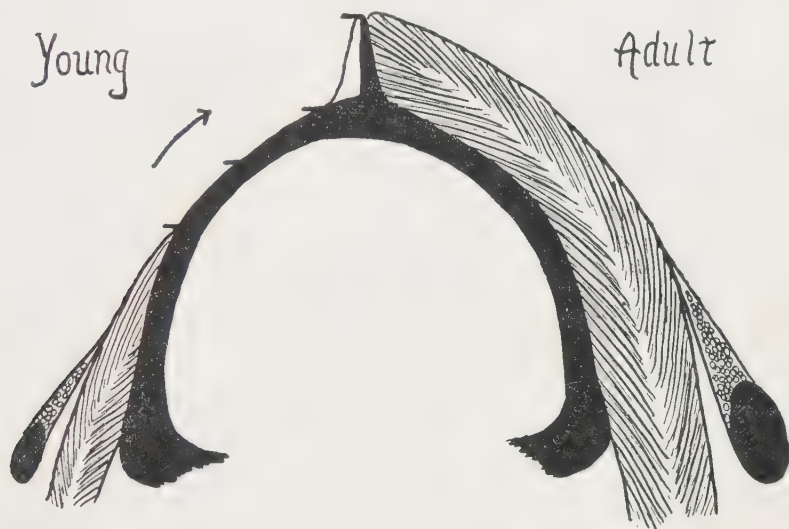


Fig. 7 Temporal muscle migration in the gorilla.

parietal bone at birth. At the time of completion of the deciduous dentition, the line has ascended three-tenths of the height of the parietal bone. By this time brain growth has almost ceased (Keith, '31). The temporal ridges reach to the middle of the parietal bone by the time of eruption of the first permanent molars and meet one another over the sagittal suture when the second permanent molars erupt. In adult male animals in which the permanent canines and third molars have erupted, a sagittal crest has been built up to give further attachment to the muscles. This crest reaches to



a height of 22 mm or more over the posterior part of the skull (fig. 7). In the male chimpanzee and orangutan less massive crests may develop. A low crest may develop in the female gorilla, while sagittal crests are absent in the other female anthropoid apes. The average cranial capacity for the anthropoid apes is as follows (Martin, '28):

	<i>cm</i>		<i>cm</i>
Male gorilla .....	508	Female chimpanzee .....	389
Female gorilla .....	435	Male orangutan .....	395
Male chimpanzee .....	404	Female orangutan .....	357

In spite of the greater cranial size, the gorilla requires a large suprasagittal crest for the temporal muscles.

Table 3, from the data provided by Ashton and Zuckerman ('50) gives comparative figures for the development of the dentition among anthropoid apes.

TABLE 3

ANIMAL	HEIGHT OF LOWER CANINE	OCCLUSAL LENGTH OF M1, M2 AND M3
	( <i>mm</i> )	( <i>mm</i> )
Male gorilla	28.4	51.6
Male orangutan	21.9	40.6
Male chimpanzee	17.7	32.2
Female gorilla	16.2	47.4
Female orangutan	14.9	37.1
Female chimpanzee	12.7	30.9

We have, therefore, some evidence of a correlation between growth of the temporal muscle, the formation of bony superstructures developed in relation to the muscle growth, and the degree of development of the dentition.

Bunak ('26) also finds that there is a close, but not a full, correspondence between the extent of the temporal muscle, the size of the canines, and the development of the lower jaw.

In the male baboon, in which the permanent canines and molars are much more massive than in the female, the temporal ridges of each side first meet one another over the sagittal suture at about the time of eruption of the permanent

canines. In adult animals low sagittal crests develop over the back of the skull. In adult females the temporal ridges fall short of the mid line and no crest is produced.

In long-faced dogs the temporal ridges have ascended two-thirds of the height of the parietal bones just before the replacement of the deciduous teeth by the permanent dentition, while in adult animals the temporal ridges have united in the middle line to form a sagittal crest which comes forward to about the level of the coronal suture. In dogs there is not



Figure 8

Fig. 8 Migration of temporal crest.

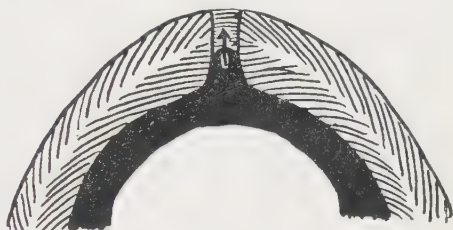


Figure 9

Fig. 9 Development of sagittal crest in the gorilla.

much difference in the degree of development of the sagittal crest in the two sexes; neither is there any great sexual difference in the dentition.

#### THE METHOD OF FORMATION OF SAGITTAL CRESTS

The temporal ridges develop where the fascia covering the temporal muscle is attached to the fibrous outer layer of the periosteum. Along the line of union of the two fibrous layers, the underlying cellular osteogenetic layer of the periosteum forms a bony ridge (fig. 8). As the muscle migrates upward and backward with growth, the bony ridge moves before it by a process of resorption and redeposition of bone until, in the male gorilla or baboon, the two ridges come together along the middle line above the sagittal suture. Here

the fasciae covering the temporal muscles of the two sides of the skull meet and run together to the underlying bone, forming a two-layered fibrous septum between the muscles. Ossification extending into this fibrous septum produces a mid line sagittal crest (fig. 9). In the same way, at the back of the skull, crests are formed between the temporal muscles and the neck muscles attached to the occipital bone.

THE DEVELOPMENT OF THE MASSETER MUSCLE  
AND THE RAMUS OF THE MANDIBLE

The masseter muscle is attached to the outer surface of the ramus of the mandible between the mandibular notch and the lower border. It is generally held that there is a correlation between the breadth of the ramus and the degree of development of the muscles of mastication.

The range of variation for the breadth of the ramus among individuals from living human races is from 23 to 50 mm. The races with the highest average measurement are the Aleutian Islanders and the Eskimos, while the lowest average is found among white races (Hrdlicka, '40).

Table 4 gives the average combined mesio-distal length of the lower permanent molars, the average breadth of the mandibular ramus and the ramus index, which is an expression of the relationship between tooth size and ramus width, the latter being correlated to the size of the masseter muscle. In Australian aborigenes the index is high because of the large size of the teeth, in U.S. whites it is high because of the small size of the ramus, which is related to the relative disuse of the muscles. Another notable fact emerging from the measurements is that while all the human material including the Heidelberg mandible, *Telanthropus* and even *Plesianthropus* fall within the wide range of 70-107 for the ramus index, the anthropoid apes fall well below this range. It will be noticed that the range of variation for tooth dimensions is less variable than that for the ramus breadth. Tooth size is regulated by genetic factors only, while ramus breadth is modified to a considerable extent by the use of the muscles of mastication.

While the size of the mandibular ramus is related to the degree of use of the muscles of mastication, certain other mandibular measurements show no such correlation. These include the total length of the body of the bone from the back of the condyles to pogonion (the most projecting point of the mental protuberance), and the bycondylar width.

TABLE 4

SOURCE	M1, M2, M3	BREADTH OF RAMUS	M/R INDEX
	(mm)	(mm)	
Lapps	31.3	33.8	92
U. S. Whites	32.6	31.1	105
Melanesians	32.8	36.7	87
Pecos Indians	34.5	36.9	93
Eskimos	34.6	39.8	87
Australians	36.7	34.3	107
Elementia "A"	34.5	37.5	92
Elementia "E"	37	37	100
Tabūn 2	33.3	40	83
Skhūl 4	32.6	42.5	77
Skhūl 5	34.3	36.2	95
Heidelberg	36.5	52	70
Sinanthropus	38	40.7	93
Plesianthropus	44.8	56	80
Telanthropus	39.4	45	88
Chimpanzee	32.2	31.8	62
Gorilla	51.6	85	61

Data from Hrdlicka ('40), McCown and Keith ('39), Leakey ('33), Selmer-Olsen ('49), Pedersen ('49), Ashton and Zuckermann ('50), Nelson ('38), Weindenreich ('36), Dart ('55).

Hrdlicka ('40) stated that variability between the jaws of living human races is least for mandibular length and greatest for breadth of the ramus and thickness of the body. Bicondylar width is related to the width of the cranial base which carries the glenoid fossae. The length of the mandible is related to the stature of the body. As the stature increases, however, the relative length of the mandible decreases (Hrdlicka, '40; Shepherd, Sholl and Vizoso, '49); that is, the rate of growth of the mandible lags behind the rate of

skeletal growth. The lack of any direct correlation between mandibular length and breadth of the ramus may be shown by comparing the ramus breadths of the mandible in which this dimension is greatest with the mandibular lengths of the same jaws from Irish and Chinese material (table 5).

The Irish mandible with the lowest mandibular length (80 mm) has a ramus breadth of 28 mm (range 22.5 to 35 mm), and the Chinese mandible with the lowest mandibular length (91 mm) has a ramus breadth of 31.6 mm (range 24 to 39). The degree of development of the alveolar process of the mandible is also independent of the total mandibular length. In the chimpanzee, a much more massive alveolar process is

TABLE 5

IRISH SERIES, (MCLOUGHLIN, '50)			CHINESE SERIES (HARROWER, '28)		
Number	Ramus breadth (mm)	Mandible length in mm	Number	Ramus breadth (mm)	Mandible length in mm
(Range 80 to 117)			(Range 91 to 119)		
295	35	104	120	39.0	105.0
C.K.A.	35	114	100	38.0	119.0
167	34	106	93	37.5	102.6
284A	34	112	102	36.8	106.2
336	34	117	132	36.5	94.5
104	33	113	108	36.5	110.0

built up on a mandibular body of dimensions somewhat similar to that found in living human races. In modern man the chin is an expression of a reduction of the alveolar element, not of an increase in the length of the body of the mandible. It is interesting to notice that those elements in mandibular growth which are least affected by the degree of development of the muscles of mastication or of the dentition depend upon the conversion of cartilage into bone, and in this respect there is a similarity between the growth in length of the mandible and the growth of a long bone. We have noticed already that such conditions as muscle paralysis have much less effect upon the length of a limb bone, which depends upon cartilage growth, than upon its thickness and the de-



velopment of its muscular processes, which depend on the relationship of bone deposition to bone absorption.

The comparative anatomy of the region of the angle of the mandible is of considerable interest (Washburn, '51). It gives attachment to both the masseter and internal pterygoid muscles. In carnivorous marsupials the angle region reaches its fullest degree of development and shows two well developed flanges, an inner for the pterygoid muscle, an outer for the masseter. Backward projecting processes for the common attachment of these muscles are found in many carnivores, rodents, insectivores and in lemurs. In massive male human mandibles there is often an eversion of the lower border of the jaw at the angle which indicates the method of development of the marsupial flange. *Glyptodon*, an extinct edentate (Romer, '45), shows a large vertical process descending from the zygomatic arch to which the masseter was probably attached so as to change the direction of the action of at least some of its fibres to a horizontal position.

#### THE FUNCTIONAL RELATIONSHIP BETWEEN MUSCLE AND NERVE

It has long been known that when the motor nerve to a muscle is cut the muscle undergoes atrophy. Tower ('31) described three stages in this process. First, there is a period of up to 7 days in which the muscle is inactive and the nerve tissue remaining in contact with the muscle degenerates. The second stage is initiated by the onset of spontaneous, rhythmic, fibrillar contractions. This stage may continue for a considerable time and is associated with reduction in the size of the individual fibres without, however, any loss of the characteristic fibre structure. Finally, the muscle degenerates and is replaced by fibrous tissue. Tower ('37) also has shown that the trophic state of skeletal muscle, which is abolished with nerve section, depends entirely upon the motor innervation and is not related to the sensory or autonomic nerve supply of the muscle. "Like 'tonic state' 'trophic state' becomes in this light one aspect of the function

of the neuromotor unit." Gutmann ('45) produced evidence showing that motor nerve fibres are able to arrest and reverse atrophic changes, even after long periods of denervation, provided they can make contact with the muscle tissue. Recovery is indicated by increase in the diameter of the muscle fibres, decrease of connective tissue, and the return of the nuclei of the muscle fibres to their original shape and position.

Atrophy of a much more limited nature occurs if a muscle is not used. "Disuse atrophy" has been studied by Chor and Dolkart ('36) in the monkey. Limbs were encased in plaster of Paris. Within one week there was evidence of decrease in muscle bulk. The atrophic process was very slow, however, and there was no evidence of degeneration or of any change in the size and structure of the anterior horn cells of the spinal cord or of the nerve fibres from the spinal cord to the immobilized limb. Smith ('28) described a muscle in a human leg which, owing to the absence of the tibia, arose and was inserted to the same bone, the fibula. This muscle performed no function, but as its nerve supply was intact, its structure was normal and there was no evidence of atrophy or degeneration. In man there is a marked decrease in the number of motorhorn cells after the fifth decade of life (Gardner, '40). Atrophy of muscle begins to show itself at about the same time.

Aitken ('49) has shown that the maturation of a regenerating nerve is much more complete when the fibres make contact with denervated muscle fibres than when the nerve grows into normal muscle or fascia, while Sanders and Young ('46) state that both sensory and motor nerve fibres enlarge when allowed to reach their end organs although motor nerves enlarge more than sensory nerves.

Sometimes disease of peripheral nerves, such as polyneuritis, results in abnormal regeneration and associated hypertrophy of the related muscles (Krabbe, '34). A condition of unilateral or bilateral hypertrophy of the masseter muscles has been described (Maxwell and Waggoner, '51). In such cases there is a great increase in size on the part

of some of the muscle fibres. The condition is sometimes associated with hypertrophy of other muscles and often with evidence of disorder of the central nervous systems. A common finding is an increase in the size of the angular region of the mandible with outward eversion of the lower border of the bone.

Edds ('50) has shown that when the functional load of a muscle is increased to cause it to hypertrophy in the rat, the myelinated fibres in its motor nerve also increase in size. Agduhr ('20) and Wedeles ('49) obtained similar results for the mouse and rabbit.

From the evidence here produced it appears probable that the motor nerves to striped muscle are responsible not only for their tone, contraction, and relaxation, and for maintaining the normal size and structure of the muscle fibres (trophic action), but also for their growth. It is significant that nerve and muscle are similar in that both early lose the power of growth by cell division but continue to grow by increase in cell size or hypertrophy in relation to the demands of function (Smith, '32). In the cat there is an increase of 157% in the diameters of myelinated fibres in the oculo-motor nerve from birth to 6 months of age (Boughton, '06). In the albino mouse the ventral-horn cells of the spinal cord increase rapidly in size from birth to the twentieth day and attain full size at the thirtieth day (Ngowyang, '30). In the albino rat, growth of the sciatic nerve in cross section increases rapidly up to 63 days, is slower up to 250 days, and from then to old age is continuous but again less rapid (Ide, '29). Nittono ('20) has shown that the diameter of the nerve fibres in the fifth cranial nerve in the albino rat increases very rapidly from birth up to 20 days, then at a slower rate up to 100 days, and then steadily but slightly up to 485 days when observations were discontinued. This is a different rate of growth from that found in the sciatic nerve and appears to be related to tooth eruption. The times of eruption of the teeth of the rat are: incisors, tenth to sixteenth day; first molar, nineteenth to twenty-fifth day; second molar, twenty-

second to twenty-eighth day; and the third molar, thirty-fifth to fortieth day. The figures in each case give the time of first cutting the gum and the attainment of occlusion (Schour and Massler, '42). The incisors receive a more extensive nerve supply than the other teeth and in these teeth the greater number of the fibres enter the periodontal membrane on the lingual cement-covered side of the tooth. In rodent incisors only the lingual cement-covered surface has a true periodontal membrane. The buccal enamel-covered surface is separated from the alveolar bone by loose connective tissue. Mohiuddin ('51) analyzed the fibres of the inferior dental nerve in kittens and adult cats. In the newborn kittens the myelinated fibres are between  $2\mu$  and  $5\mu$  in diameter. In adult cats two types of medullated fibres are present: (a) small fibres about  $4\mu$  in diameter and (b) large fibres about  $10\mu$  in diameter. The number of nerve fibres does not increase after birth, and growth in size of the fibres is complete by the fifth month. The larger fibres include those which have their sensory end organs in the periodontal membrane (Brashear, '36; Lewinsky and Stewart, '37). The permanent teeth erupt between the fifth and seventh months. In the inferior dental nerve of the cat, 26.7% of the fibres arise in the canine-incisor region, 13.4% in the premolar region, and 12% in relation to the carnassial (molar) tooth. The remaining fibres come from the mental nerve (Thomas, '46).

It would appear that both motor and sensory nerves continue to grow after birth and that this growth is associated with muscle growth (Herrick, '25; Detwiler, '26). Fernard and Young ('51) state that it is probable that the activity of the sensory or motor periphery connected with a nerve fibre influences the diameters of the fibre and cell to some extent, and it is almost certain that the amount of stimulation falling upon the cell dendrites has an important effect. Furthermore, the sensory nerves associated with the teeth increase in size as the dentition develops, and in animals with well-developed incisors or canines a large number of sensory



fibres arise in association with the periodontal membrane of these teeth.

#### SENSE ORGANS, NERVOUS SYSTEM AND MUSCLE ACTION

Evans ('52) has shown the correlation existing between feeding habits and brain pattern in 4 species of cyprinid fishes. The feeding habits are associated with the development of specialized taste buds on the palate, sensory lips, or snout, in one group, and on sight in another group. According to which type of sensation is used, different parts of the brain become enlarged and specialized. It is therefore possible to deduct the feeding habits from an examination of brain form and structure. The relationship between specialized sense organs and brain structure is well illustrated in the eyes and visual cortex of *Tarsius*. In the birds the cerebellum is specially developed in association with the requirements of orientation in space necessary for flight (Whitlock, '52), and in whales (Jansen, '50) the development of the various parts of the cerebellum is correlated with the absence of limbs and the functional importance of the trunk and tail.

Teeth are sense organs as well as organs of mastication. The sensory nerve endings of the periodontal membrane are stimulated during mastication and act as part of the muscle regulating proprioceptive apparatus. Associated with the various specialized dentitions there is a specialized pattern of sensory nerves (Graf and Hjelmquist, '55) and of their connections within the central nervous system (Corbin, '40).

There is a tendency to treat systems such as the sense organs, brain, muscular system and skeleton as separate entities and study structure and function within each system instead of seeking to understand the functional developmental, and structural relationships which exist between the various systems. In any animal there is a close functional interaction between the pattern of sensation and that of motor function; there is a unity of structure in which the structure of the



central nervous system is but a part. A change in the pattern of sensation involving either one or more of the special senses or some part of the general body sensory apparatus will result in a change in the pattern of muscular response, which in turn involves a change in the attachments of muscles and the form of certain parts of the skeleton. Experimental evidence for such an interrelationship existing between the dentition, muscles and skull form is provided by Gruneberg ('55). In grey lethal mice the teeth are distorted during development and most of them fail to erupt. The muscles of mastication do not develop according to the typical rodent pattern, and there is an associated abnormal development of the coronoid processes, angular processes, zygomatic arches and pterygoid plates. It would appear that the failure of tooth development and eruption brought about by a breakdown in the mechanism of bone absorption is the primary factor in this pattern of abnormal development.

In foetal rats the first response to tactile stimulation occurs in the snout region (Angulo, '32). Angulo has also shown ('50) that differentiation of the trigeminal ganglion is well in advance of those of the spinal ganglia and that the fifth cranial nerve is well developed at a stage when the spinal nerves are just about to enter the developing limb buds. Barcroft ('41) has shown that the muscles of the head and neck become active before those of the trunk and limbs. It is interesting to notice the association of the primary neuromuscular differentiation in the head and neck region with the appearance of the earliest ossification centres which appear in premaxillary, maxillary and mandibular bones and in the clavicle. In the vertebral column ossification centres for the arches (to which the muscles are attached) appear in the upper cervical region and succeed one another in series along the column from above downwards, while the centres for the vertebral bodies, which are more closely related to the distribution of body weight, appear first in the lower thoracic region (Noback and Robertson, '51).

## DISCUSSION AND SUMMARY

At the present time a vast amount of experimental data is accumulating in all branches of biology. Many of the problems of anthropology might be brought closer to their ultimate solution by using these experimentally established facts in order to create undogmatic and experimental hypotheses to be used as instruments of scientific speculation. In this paper a selection of the available information has been brought together in order to obtain some understanding of certain of the problems involved in the relationship of muscle growth and function to skeletal form. From this study a number of speculative and tentative hypotheses arise which may be worth testing by further experiments. These include:

1. The neuro-muscular unit (the motor nerve and its associated muscle fibres) is not only a unit of muscle function but is also, through its power of controlling muscle growth and migration, an instrument whereby the central nervous system can produce extensive changes in skeletal morphology.

2. The growth and morphological differentiation of the skeleton appears to depend on two distinct processes: (a) a length regulating process controlled by the conversion of cartilage into bone, which is concerned in the growth in length of the limb bones, the cranial base, the vertebral column, and the body of the mandible, and is regulated by the growth promoting hormones; (b) a robustness regulating process which determines the thickness of the limb bones, the size of the vertebrae, the development of areas of muscle attachment and of the facial buttress system, and which in anthropoid apes produces the sagittal and occipital crests of the skull. This process is regulated by the activity of the subperiosteal cellular tissue and does not involve the growth cartilages. Much of the difference between the male and female gorilla is an expression of this process and it also contributes to the difference between the skeleton of the Eskimo and the

Lapp, and between Upper Palaeolithic man and modern man. Indirectly, the greater development of the body musculature affects the size of the skull through the correlated increase in size of the brain. The robustness factor of skeletal development is superimposed upon the length regulating process so that strong thick bones may be found in dwarfs as well as in giants. Robustness is related to the action of the sex hormones as well as the use of the musculature, the ability of the body to make full use of available nutrition, and also to the effect of the physical environment (Coon, '53).

3. Within a species, and especially in a polytypical species such as man and the dog, a large number of morphological features are latent and only find expression in the co-ordinated activity of genetic and environmental factors. In this the genetically determined plasticity of the skeleton, which enables it to respond to variations in functional activity, is important. An implication of this "latent plasticity" may be the incorporation of Neanderthal type of man in the same species category as modern man with perhaps the further extension to include *Sinanthropus* and *Pithecanthropus* as suggested by Dobzhansky ('44) and Weidenreich ('46). Another aspect of this hypothesis is the possibility that much of the evidence for the development of new species within recent times is merely the appearance of morphologically distinct groups within a widely adapting species. We require more knowledge on the range of morphological adaptation within a species before we can have a full knowledge of what exactly is involved in the origin of a new species.

#### LITERATURE CITED

- ABBIE, A. A. 1947 Headform and human evolution. *J. Anat.*, 81: 233.  
AGDUHR, E. 1920 Studien über die postembryonale Entwicklung der Neuronen und die Verteilung der Nuriten in den Wurzeln der Spinalneuren. *J. Psychol. Neur.*, 25: 463.  
AITKEN, J. T. 1949 The effect of peripheral connections on the maturation of regenerating nerve fibres. *J. Anat. Lond.*, 83: 32.  
ANGULO, A. W. 1932 The prenatal development of behaviour in the albino rat. *J. Comp. Neur.*, 55: 395.

- ANGULO, A. W. 1951 A comparison of the growth and differentiation of the trigeminal ganglia with the spinal ganglia in albino rat embryos. *J. Comp. Neur.*, 95: 53.
- APPLETON, A. B. 1934 Postural deformities and bone growth. *Lancet*, 226: 451.
- ASHTON, E. H., AND S. ZUCKERMAN 1950 Some quantitative dental characteristics of the chimpanzee, gorilla and orang-utan. *Trans. Roy. Soc.*, 234B: 471.
- BARCROFT, J. 1941 Evolution of function in the mammalian organism. *Nature*, Lond., 147: 762.
- BARDEEN, C. R. 1906 Development and variation of the nerves and musculature of the inferior extremity and of neighbouring regions of the trunk in man. *Am. J. Anat.*, 6: 259.
- BECHTOL, C. O., AND H. W. MOSSMAN 1950 Club-foot. An embryological study of associated muscle abnormalities. *J. Bone and Joint Surg.*, 32A: 827.
- BLOOM, W., M. A. BLOOM AND F. C. McLEAN 1941 Calcification and ossification. Medullary bone changes in the reproductive cycle of female pigeons. *Anat. Rec.*, 81: 443.
- BOUGHTON, T. H. 1906 The increase in number and size of the medullated fibres in the oculomotor nerve of the white rat and of the cat at different ages. *J. Comp. Neur.*, 16: 153.
- BRASH, J. C. 1934 Some problems in the growth and developmental mechanics of bone. *Edinburgh M. J.*, 41: 305.
- 1956 "The Aetiology of Irregularity and Malocclusion of the Teeth." 2nd ed. Dental Board. U.K.
- BRASHEAR, A. D. 1936 The innervation of the teeth. *J. Comp. Neur.*, 64: 169.
- BREMER, J. C. 1940 The pneumatization of the humerus in the common fowl and the associated activity of theelin. *Anat. Rec.*, 77: 197.
- BUNAK, V. 1926 The crest on the skull of primates. *Russ. Anthropol. J. Moscow* 12 (Quoted by Harris, H. A., *Am. J. Phys. Anthropol.*, 9: 169, 1926.)
- CAMERON, J. 1923 Report of the Canadian Arctic Expedition 1913-18, 12. The Copper Eskimos. Part C.
- CHOR, H., AND R. E. DOLKART 1936 A study of simple disuse atrophy in the monkey. *Am. J. Physiol.*, 117: 626.
- COLLINS, H. B. 1950 The origin and antiquity of the Eskimo. *Ann. Rep. Smithsonian Inst. for 1950*, p. 423.
- COON, C. 1953 Climate and race. *Ann. Rep. Smithsonian Inst. for 1953*, p. 423.
- CORBIN, K. B. 1940 Observations on the peripheral distribution of fibres arising in the mesencephalic nucleus of the fifth cranial nerve. *J. Comp. Neur.*, 73: 153.
- DART, R. 1955 *Australopithecus prometheus* and *Telanthropus capensis*. *Am. J. Phys. Anthropol.*, 13 N.S.: 67.
- DETWILER, S. R. 1926 Experimental studies on morphogenesis in the nervous system. *Quart. Rev. Biol.*, 1: 61.
- DICKSON, L. M. 1940 The development of nerve endings in the respiratory muscles of the sheep. *J. Anat. Lond.*, 74: 268.

- DOBZHANSKY, T. 1944 On species and races of living and fossil man. *Am. J. Phys. Anthrop.*, 2 N.S.: 251.
- EASTLICK, H. L. 1943 Studies on transplanted embryonic limbs of the chick. *J. Exp. Zool.*, 93: 27.
- EDDS, M. V. 1950 Hypertrophy of nerve fibres to functionally overloaded muscles. *J. Comp. Neur.*, 93: 259.
- EDGEWORTH, F. H. 1935 "The Cranial Muscles of Vertebrates." London: Cambridge University Press.
- EVANS, H. E. 1952 The correlation of brain pattern and feeding habits in four species of cyprinid fishes. *J. Comp. Neur.*, 97: 133.
- FAWCETT, D. W. 1942 The amedullary bones of the Florida manatee. *Am. J. Anat.*, 71: 271.
- FAWCETT, E. 1924 The development of the bones around the mouth. Dental Board Lectures. Dental Board, U.K.
- FERNARD, U. S. V., AND J. Z. YOUNG 1951 The size of the nerve fibres of muscle nerves. *Proc. Roy. Soc.*, 139B: 38.
- FRIEL, S. 1926 An investigation into the relation of function and form. *Brit. Dent. J.*, 47: 353.
- GARDNER, E. 1940 Decrease in human neurones with age. *Anat. Rec.*, 77: 529.
- GILLESPIE, J. A. 1954 The nature of the bone changes associated with nerve injuries and disuse. *J. Bone and Joint Surg.*, 36B: 464.
- GRAF, W., AND U. HJELMQUIST 1955 Caliber spectra of dental nerves in dogs and cattle. *J. Comp. Neur.*, 103: 345.
- GRÜNEBERG, H. 1935 A new sub-lethal colour mutation in the house mouse. *Proc. Roy. Soc.*, B118: 321.
- GUTMANN, E. 1945 The reinnervation of muscle by sensory nerve fibres. *J. Anat. Lond.*, 79: 1.
- HAINES, R. W. 1932 The laws of muscle and tendon growth. *J. Anat. Lond.*, 66: 578.
- HALL, E. K. 1950 Experimental modifications of muscle development in *Amblystoma punctatum*. *J. Exp. Zool.*, 113: 335.
- HARRIS, H. A. 1926 Endocranial form of gorilla skulls. *Am. J. Phys. Anthrop.*, 9: 157.
- HARRISON, R. G. 1904 Relation of the nervous system to the developing musculature. *Am. J. Anat.*, 3: 197.
- HARROWER, G. 1928 A biometric study of 110 Asiatic mandibles. *Biometrika*, 20: 279.
- HERRICK, C. J. 1925 Morphogenetic factors in the differentiation of the nervous system. *Physiol. Rev.*, 5: 112.
- HEWER, E. E. 1927 The development of muscle in the human foetus. *J. Anat. Lond.*, 62: 72.
- 1935 The development of nerve endings in the human foetus. *J. Anat. Lond.*, 69: 369.
- HOLMGREN, H. 1940 Beitrag zur Kenntnis des Verhältnisses zwischen der Skelettmuskulatur des Unterarms und dem M. pronator quadratus während der Entwicklung des Menschen. *Anat. Anz.*, 89: 1.
- HOOTON, E. A. 1918 On certain Eskimoid characters in Icelandic skulls. *Am. J. Phys. Anthrop.*, 1: 58.



- HOROWITZ, S. L., AND H. SHAPIRO 1955 Modification of skull and jaw architecture following removal of the masseter muscle in the rat. *Am. J. Phys. Anthrop.*, 13 N.S., 301.
- HRDLICKA, A. 1914 The most ancient skeletal remains of Man. *Smithsonian Report for 1913*, p. 515.
- 1932 The principal dimensions absolute and relative of the humerus in the white race. *Am. J. Phys. Anthrop.*, 16: 431.
- 1935 The Pueblos. *Am. J. Phys. Anthrop.*, 20: 235.
- 1940 Lower jaw. Further studies. *Am. J. Phys. Anthrop.*, 27: 383.
- HUMPHREY, G. M. 1862 On the influence of paralysis, etc. upon the growth of bones. *Med. Chir. Trans. Lond.*, 45: 283.
- IDE, K. 1929 On the areas of the cross sections of the median and sciatic nerves of the albino rat. *J. Comp. Neur.*, 48: 373.
- IMBELLONI, J. 1950 Cephalic deformities of the Indians in Argentina. *Bureau of American Ethnology Bulletin* 143. *Handbook of South American Indians*. Vol. 6, p. 53.
- JAGER, K. W., AND J. MOLL 1951 The development of the human triceps surae. *J. Anat. Lond.*, 85: 338.
- JANSEN, J. 1950 The morphogenesis of the cetacean cerebellum. *J. Comp. Neur.*, 93: 341.
- KEITH, A. 1910 Description of a new craniometer and of certain age changes in the anthropoid skull. *J. Anat. Lond.*, 44: 251.
- 1931 "New Discoveries relating to the Antiquity of Man." Chap. 3. London: Williams and Norgate.
- KRABBE, K. H. 1934 The myotonia acquisita in relation to the post-neuritic muscular hypertrophies. *Brain*, 57: 184.
- KRAHL, V. E., AND F. G. EVANS 1945 Humeral torsion in man. *Am. J. Phys. Anthrop.*, 4 N.S.: 229.
- LAYARD, D., AND M. YOUNG 1935 The Burwell skulls. *Biometrika*, 27: 388.
- LEAKEY, L. S. B. 1933 "The Stone Age Races of Kenya." Oxford University Press.
- LEWINSKY, W., AND D. STEWART 1937 The innervation of the periodontal membrane of the cat. *J. Anat. Lond.*, 71: 232.
- LOCKHART, R. D., AND W. BRANDT 1938 Length of striated muscle fibres. *Proc. Anat. Soc. J. Anat. Lond.*, 72: 470.
- LOW, A. 1910 Further observations on the ossification of the human lower jaw. *J. Anat. Lond.*, 44, 83.
- MALY, J., AND J. MATIEGKA 1938 Skeletons of pygmies from the Ituri basin. *Anthropologie*, 16: 1.
- MARTIN, R. 1928 "Lehrbuch der Anthropologie." Vol. 2. Jena: Gustav Fischer.
- MAXWELL, J. H., AND R. W. WAGGONER 1951 Hypertrophy of the masseter muscles. *Ann. Otol. Rhin. and Laryng.*, 60: 538.
- MCCOWN, T. D., AND A. KEITH 1939 "The Stone Age of Mount Carmel." Oxford University Press.
- McLOUGHLIN, E. P. 1950 Castleknock Skeletal Material. Dublin: Stationery Office.

- MEISTER, W. 1956 Changes in histological structure of the long bones of white-tailed deer during the growth of the antlers. *Anat. Rec.*, 124: 789.
- MIDDLETON, D. S. 1934 Studies on prenatal lesions of striated muscles as a cause of congenital deformity. *Edinburgh M.J.*, 41: 401.
- MOHIUDDIN, A. 1951 The postnatal development of the inferior dental nerve of the cat. *J. Anat. Lond.*, 85: 24.
- MOORREES, C. F. A., R. H. OSBORNE AND E. WILDE 1952 Torus mandibularis: its occurrence in Aleut children and its genetic determinants. *Am. J. Phys. Anthrop.*, 10 N.S.: 319.
- MOSS, M. L. 1954 Growth of the calvaria in the rat. The determination of osseous morphology. *Am. J. Anat.*, 94: 333.
- NELSON, C. T. 1938 The teeth of the Indians of Pecos Pueblo. *Am. J. Phys. Anthrop.*, 23: 261.
- NGOWYANG, GU. 1930 Growth of motor cells from birth to maturity in the albino rat. *J. Comp. Neur.*, 50: 231.
- NITTONO, K. 1920 On the growth of the neurons composing the Gasserian ganglion of the albino rat between birth and maturity. *J. Comp. Neur.*, 32: 231.
- NOBAK, C. R., AND G. G. ROBERTSON 1951 Sequence of appearance of ossification centres in the human skeleton during the first five prenatal months. *Am. J. Anat.*, 89: 1.
- PEDERSEN, P. O. 1949 The East Greenland Eskimo dentition. *C. A. Reitzels, Forlog.*
- RIDEHALGH, E., AND D. STEWART 1938 The course of the incisor branch of the inferior dental nerve in rodents. *J. Anat. Lond.*, 72: 416.
- RIESENFELD, A. 1955 The variability of the temporal lines, its causes and effects. *Am. J. Phys. Anthrop.*, 13 N.S.: 599.
- ROMER, A. S. 1945 "Vertebrate Paleontology." 2nd ed. University of Chicago Press.
- SANDERS, F. K., AND J. Z. YOUNG 1946 The influence of peripheral connections on the diameter of regenerating nerve fibres. *J. Exp. Biol.*, 22: 203.
- SCHAUDER, W. 1926 Über Entwicklung und Rückbildung des Musculus pronator quadratus des Pferdes. *Anat. Anz.*, 61: 302.
- SCHOUR, J., AND M. MASSLER 1942 "The Teeth" in "The Rat in Laboratory Investigation." London: J. B. Lippincott Company.
- SCHULTZ, A. H. 1953 The relative thickness of the long bones and vertebrae in primates. *Am. J. Phys. Anthrop.*, 11 N.S.: 277.
- SCOTT, J. H. 1951 Development of joints concerned with early jaw movement in the sheep. *J. Anat. Lond.*, 85: 36.
- 1954 The growth and function of the muscles of mastication in relation to the development of the facial skeleton and of the dentition. *Am. J. Orthodont.*, 40: 429.
- SELMER-OLSEN, R. 1949 An Odontometrical Study on the Norwegian Lapps. Oslo.
- SHEPHERD, R. H., D. A. SHOLL AND A. VIZOSO 1949 Size relationships subsisting between body length, limbs and jaws in man. *J. Anat. Lond.*, 83: 296.

- SMITH, J. L. 1932 "Growth." Oliver and Boyd, Edinburgh.
- SMITH, N. R. 1928 A note on the so-called "disuse" atrophy of muscle. *J. Anat. Lond.*, 62: 238.
- SPEIDEL, C. C. 1938 Studies of living muscle. Growth, injury and repair of striated muscle. *Am. J. Anat.*, 62: 179.
- STEWART, S. F. 1951 Club foot; its incidence, course and treatment. *J. Bone and Joint Surg.*, 33A: 577.
- SYMONS, N. B. B. 1951 Studies on the growth and form of the mandible. *Dent. Record*, 71: 41.
- THOMAS, B. O. A. 1946 An analysis of the inferior dental and mental nerve in the cat. *J. Comp. Neur.*, 84: 419.
- THOMSON, A. 1903 On man's cranial form. *Int. Med. Congress.*
- TOWER, S. S. 1931 A search for trophic influence of posterior spinal roots on skeletal muscle. *Brain*, 54: 99.
- 1937 Trophic control of non-nervous tissue by the nervous system. *J. Comp. Neur.*, 67: 241.
- 1939 The reaction of muscle to denervation. *Physiol. Rev.*, 19: 1948.
- TOWNSLEY, W. 1948 The influence of mechanical factors on the development and structure of bone. *Am. J. Phys. Anthropol.*, 6 N.S.: 25.
- TROTTER, W. 1941 "The Functions of the Human Skull" from *The Collected Papers of Wilfred Trotter*. London: Oxford University Press.
- VAN DEN BROEK, A. J. P. 1943-45 On exostoses in the human skull. *Acta Neerlandica Morph.*, 5: 95.
- WASHBURN, S. L. 1947 The relation of the temporal muscle to the form of the skull. *Anat. Rec.*, 99: 239.
- 1950 The analysis of primate evolution with particular reference to the origin of man. *Cold Spring Harbor. Quart. Biol.*, 15: 67.
- 1951 The new physical anthropology. *N. Y. Acad. Sci.*, 13: 298.
- WAUGH, L. M. 1937 Dental observations among Eskimos. *J. Dent. Res.*, 16: 355.
- WEDELES, C. H. A. 1949 The effect of increasing the functional load of a muscle on the composition of its motor nerve. *J. Anat. Lond.*, 83: 57.
- WEIDENREICH, F. 1936 The mandibles of *Sinanthropus Pekinensis*, *Palaeont Sinica*, Ser. D, 7.
- 1940 The brain and its role in the phylogenetic transformation of the human skull. *Trans. Am. Philos. Soc.*, 31: 321.
- 1946 Generic, specific and subspecific characters in human evolution. *Am. J. Phys. Anthropol.*, 4 N.S.: 413.
- WEINMANN, J. P., AND H. SICHER 1955 "Bone and Bones. Fundamentals of Bone Biology." 2nd edition. London: Henry Kimpton.
- WHITLOCK, D. G. 1952 A neurohistological and neurophysiological study of afferent fibre tracts and receptive areas of the avian cerebellum. *J. Comp. Neur.*, 97: 567.
- WINDLE, W. F., AND J. E. FITZGERALD 1937 Development of the spinal reflex mechanisms in human embryos. *J. Comp. Neur.*, 67: 493.

- WOLFFSON, D. M. 1950 Scapula shape and muscle function. *Am. J. Phys. Anthrop.*, 8 N.S.: 331.
- Woo, J. K. 1950 Torus palatinus. *Am. J. Phys. Anthrop.*, 8 N.S.: 81.
- WRIGHT, R. D. 1934 Factors concerned in bone structure. *J. Anat. Lond.*, 69: 89.

# LINGUISTIC BARRIERS TO GENE-FLOW

## THE BLOOD-GROUPS OF THE YAKIMA, OKANAGON AND SWINOMISH INDIANS

FREDERICK S. HULSE

*University of Washington, Seattle, Washington*

The Yakima, Okanagon and Swinomish are Indian groups residing in the State of Washington and in British Columbia. It would be improper to call them tribes; rather, each of them is a collection of bands and families who now recognize a certain degree of ethnic affinity. Each of the three groups occupies its own territory, at some distance from the others, and there has been little intermingling between them in recent times. None of the three groups, however, may be considered in any sense endogamous. For well over a century they have had contact with Europeans, and for half a century at least, with Asiatics as well.

Both the Swinomish and the Okanagon speak Salishan dialects, while the Yakima belong to the Sahaptin linguistic stock. The Swinomish are, however, a Puget Sound group, while the Okanagon and the Yakima live east of the Cascades, in the Columbia River Valley. Insofar as culture is concerned, the Swinomish are a Northwest Coast people, whereas both the Okanagon and Yakima are classified as Plateau.

A comparison between these three Indian groups, from a genetic viewpoint, may therefore cast some light upon the relative importance of linguistic barriers on the one hand and of other cultural and geographical barriers on the other hand, in impeding gene-flow from one group to another. Of course, neither sort of barrier is ever a complete one, as the briefest consideration of the world-wide distribution of blood groups will show (Boyd, '39; Mourant, '54). Furthermore, each of



the groups under consideration has received some increment of non-Indian genes during the past few generations, as might be anticipated. Again, evidence exists that selection has played a part in the distribution of blood-types (Brues, '54; McConnell, '56). In the present paper, an attempt is made to discount the effects of miscegenation, but the effect of possible selection is not, as yet, amenable to calculation for these groups.

In a previous paper (Hulse, '55) the distribution of blood groups among certain Coastal Indians of Washington and British Columbia was reported. The collection and analysis of blood-samples of the Indian peoples of the Northwest still continues, financed, as before, by the State of Washington from funds provided by license fees of bars and taverns. It is being extended, year by year, to include as large a number of groups as possible. Blood from members of the three groups discussed in this paper was collected and typed by graduate students of the Department of Anthropology at the University of Washington, under the supervision of the author. No attempt was made to restrict the sample to alleged "pure-blooded Indians" because experience has shown that few such individuals may be positively identified. As much information as possible was collected concerning the ancestry of each individual in the sample, and these data are taken into account in estimating the degree of non-Indian ancestry of each of the three groups, and in dividing them into subgroups labeled Indian, Doubtful, and Mixed.

In testing the Swinomish and Okanagon, the slide test was used for all blood groups. Sera used were anti-A, anti-B, absorbed anti-A, anti-C, anti-D, anti-E, anti-M, and anti-N, obtained from the Ortho Laboratories. The Yakima were tested also with anti-c and anti-Duffy. Among them, the rhesus factors were tested by means of the capillary test, and the indirect Coombes test used for the Duffy determinations. Sera used were from Ortho, Wadleigh and Certified Donor's Service.

The Swinomish Reservation centers around La Connor, at the mouth of the Skagit River about 60 miles north of Seattle. The greater number of Indians tested at this location call themselves either Swinomish or Skagit, although there is a scattering representation of other neighboring groups. Inter-marriage throughout the whole Puget Sound area has been so extensive for so many generations, however, that almost everyone knows of some ancestors from villages as much as 100 miles away. A great many of them are aware of Caucasian, Oriental, or Negroid ancestry as well. Apparently more miscegenation took place two or three generations ago than is occurring today. Blood group distributions, in all factors tested, suggest that the degree of Caucasian ancestry is rather less than among other Puget Sound Indians.

The Okanagon live in the Okanagon Valley, east of the Cascades, centering around Westbank in British Columbia and Oroville in Washington. These towns are not far apart, and are located about 150 miles east of La Connor. Aboriginal trails lead across the Cascade range which separates the Plateau from the Coast, but there are no accounts of inter-marriage between the Okanagon and any Coastal peoples. Although Salishan languages are spoken on both sides of the mountains, the evidence of glottochronology would indicate a linguistic separation between the Coastal and Plateau Salish for at least 3000 years (Swadesh, '50). Some degree of non-Indian ancestry is acknowledged among the Okanagon, and the blood-group distribution suggests that the Negroid element is greater than among the Swinomish.

The Yakima hold title to a very large reservation in the Yakima Valley, 200 miles south of the Okanagon and an equal distance southeast of the Swinomish. The Public Health Clinic at White Swan was the headquarters for work among them, and laboratory facilities were made available there for the work of typing the blood samples collected. Numerous bands and families, mostly of Sahaptin speech, from other sections of the Plateau have come to live on the Yakima reservation and have, to some extent, merged with the original

Yakima by intermarriage. Intermixture with Puget Sound or other Coastal peoples appears to have been very slight, however. Some degree of Caucasian ancestry is recognized, but not as much as among the Salishan peoples.

#### RESULTS

The results of the blood-grouping survey of the Yakima, Okanagon and Swinomish are presented in the following tables. They are divided into three sections each. In the first are included individuals alleged to have some degree of non-Indian ancestry. In the second are included individuals having blood-groups which, in my opinion, indicate non-Indian ancestry, and their children. In the third section are included individuals concerning whom there is no evidence of non-Indian ancestry. It is quite possible, of course, that such ancestry exists, but it cannot be demonstrated.

Blood-groups which indicate non-Indian ancestry are  $A_2$ , B,  $R_o$ , and r. Such blood-groups have been found among other American Indian groups only in a very few instances and almost always under circumstances which suggest admixture with Europeans, Asians or Africans. By listing individuals with such blood-groups separately, it becomes possible for the reader to include them with the Mixed or with the Indian group as he judges fit.

In table 1, the phenotypes and gene frequencies of the ABO system are presented. Whether or not one compares the Indian or the total group, the greater frequency of  $A_1$  among both Okanagon and Yakima, as contrasted to Swinomish, is very clear, being of the order of three to two, or more. Gene frequencies have been calculated for the Indian group, for the Indian and Doubtful groups combined, and for the total population.

In table 2 the phenotypes and gene frequencies of the MN system are presented. It will be noted that the Swinomish and the Okanagon resemble one another closely in the relative frequency of the alleles M and N. As noted in a previous publication (Hulse, '55), those Salish who live near the mouth of

TABLE 1  
*The ABO system*

	PHENOTYPE DISTRIBUTION					GENE FREQUENCIES			
	O	A <sub>1</sub>	A <sub>2</sub>	B	A <sub>1</sub> B	O	A <sub>1</sub>	A <sub>2</sub>	B
Swinomish 149	117	25	3	4	..	.886	.080	.020	.014
Mixed	19	8	..	1	..	}	.900	.060	.027
Doubtful	8	5	3	3	..				
Indian	90	12	..	..	..				
Indian	90	12	..	..	..	.939	.061	...	...
Okanagon 118	72	35	1	8	2	.781	.158	.017	.044
Mixed	1	6	..	1	..	}	.803	.130	.019
Doubtful	13	15	1	7	2				
Indian	58	14	..	..	..				
Indian	58	14	..	..	..	.898	.102	...	...
Yakima 125	86	36	2	1	..	.831	.144	.021	.004
Mixed	8	5	..	..	..	}	.833	.134	.025
Doubtful	7	7	2	1	..				
Indian	71	24	..	..	..				
Indian	71	24	..	..	..	.876	.124	...	...

TABLE 2  
*The MN system*

	PHENOTYPE DISTRIBUTION			GENE FREQUENCIES	
	M	MN	N	M	N
Swinomish 147	80	61	6	.752	.248
Mixed	14	13	1	}	.244
Doubtful	8	10	..		
Indian	58	38	5		
Indian	58	38	5	.756	.244
Okanagon 118	72	41	5	.752	.248
Mixed	6	2	..	}	.216
Doubtful	26	12	..		
Indian	40	27	5		
Indian	40	27	5	.777	.223
Yakima 124	54	64	6	.743	.257
Mixed	7	5	..	}	.306
Doubtful	6	9	2		
Indian	41	50	4		
Indian	41	50	4	.694	.306
Indian	41	50	4	.683	.317
Indian	41	50	4	.695	.305

the Fraser River, as well as the Kwakiutl, who live farther north, have a relatively high frequency of N, as contrasted to other Coastal peoples, whether Salish or non-Salish. Among the Yakima, however, there is a still greater frequency for this gene: greater than among any other group of American Indians yet published. Gene frequencies have been calculated for the Indian group, for the Indian and Doubtful groups combined, and for the total population.

TABLE 3  
*The RH system*

	PHENOTYPE DISTRIBUTION						
	CDE	cDE	CDe	CcDE	CcDe	cDe	cde
Swinomish 119	79	22	17			3	2
Mixed	13	4	3			1	2
Doubtful	11	1	3			2	..
Indian	51	17	11			..	..
Okanagon 114	66	15	20			12	1
Mixed	5	3	..			..	..
Doubtful	18	4	2			12	1
Indian	43	8	18			..	..
Yakima 112	9	59	13	20	1	8	2
Mixed	1	5	..	1	..	2	1
Doubtful	..	7	1	..	1	6	1
Indian	8	47	12	19	..	..	..

In table 3, the phenotypes in the RH system are presented. Chromosome frequencies were calculated for the RH system, but are not presented because the author is convinced that none of the three populations has reached genetic equilibrium. Chi-square tests indicate a considerable discrepancy between observations and expectations in the RH system. Despite this fact, it is clear that the Okanagon and Swinomish do not differ greatly in this system, whereas the Yakima are most distinctive, with an exceptionally high frequency of cDE ( $R_2$ ). Indeed, the frequency of the phenotype  $R_2$  among the Yakima is almost unique, being approached only among the Carrier (Chown, '54), and the Chippewa (Matson, '54). It will be



noted that  $R_0$  and  $r$  are found in all the tribes. The former is far more common among the Okanagon than among either the Yakima or the Swinomish: the latter is very rare in any of the groups.

#### DISCUSSION

The amount of miscegenation in all three groups of Indians has obviously been considerable, but the blood group data would indicate that it has been greatest among the Okanagon. The fact that it has been going on for a long time in all three groups, however, is indicated by the fact that individuals more than 70 years old are to be found in each of the Mixed groups. Since miscegenation continues, genetic equilibrium has not been attained, at least in the RH system. There is a clear excess of  $R_1/R_2$  heterozygotes among both Salish groups, and of MN heterozygotes among the Yakima. This could be due to the small size of the samples or, quite possibly, to selection.

The chief distinction of the Swinomish is in their very high percentage of the gene O. A few of the other Northwest Coast peoples, as reported by the author in a previous paper (Hulse, '55), the Ute (Matson, '47), the Diegueño (Pantin, '53), and the Sioux (Matson, '33), are the only other North American Indians exceeding them in this respect, so far as we yet know. The Swinomish resemble a good number of the American Indian tribes in the gene distribution of the MN system. There is no difference in the gene frequencies of the MN system, between the Indian and the Mixed sections of the Swinomish. In the RH system, the excess of the phenotype  $R_z$  (CDE) is clear, but possibly deceptive, since no serum was available for testing the presence of little  $c$ . Nevertheless, family studies indicate that there can be no question of the presence of the rare chromosome  $R_z$  which is known to exist among some, but not all, American Indian tribes.

The Okanagon do not differ significantly in the frequency of  $N$ , of  $R_1$  or of  $R_2$  from the Swinomish. Miscegenation appears to have lowered, rather than raised, the percentage of  $N$ . Chi-square tests indicate that the difference in the fre-

quency of A between Swinomish and Okanagon is certainly significant for the Indian and Doubtful groups combined, but rather less certainly significant for the Indian group alone. The chromosome  $R_z$  appears to exist among the Okanagon just as it does among the Swinomish.

The high percentage of  $R_o$  among the Doubtful section of the Okanagon, accompanied as it is by a high percentage of B, suggests strongly that miscegenation has not been restricted to matings with Europeans. Most of the Europeans in this part of America are of Northwest European origin, among whom such genes are very rare indeed. I cannot escape the suspicion that these genes were introduced by Africans or Asians, at least in part.

As in the case of the two Salish groups, such miscegenation as has taken place among the Yakima does not appear to have increased the frequency of the gene N, nor has it increased the frequency of  $Fy^b$ . The considerable percentage of  $R_o$ , however, suggests that, as with the Okanagon, some African admixture has taken place. The almost total absence of B suggests that there has been little or no Asian contribution to the present genetic structure of this people. Possibly  $R_o$  is really aboriginal.

The Yakima differ sharply from the two Salish groups in the frequency of N and of  $R_z$ , and in the RH system the difference is greatest between Yakima and Okanagon. Chi-square tests indicate that the difference in the frequency of N between the Salish and the Yakima is very probably significant and that the difference in the frequency of  $R_z$  is most significant indeed. The phenotype  $R_z$  is, to be sure, more commonly found among American Indians than among other peoples, but very rarely as frequently as in the case of the Yakima. Despite the absence of natural barriers between them, and the similarity of their Plateau cultures, the evidence suggests that the Yakima and Okanagon have not interbred to any great degree. This is a rather striking contrast to the demonstrated high degree of intermixture among all of the Puget Sound, and most of the neighboring Coastal peoples. As I pointed out in

a previous paper (Hulse, '55) the marriage systems of the Northwest Coast peoples, motivated largely as they were by the search for prestige, disregarded tribal and linguistic barriers almost completely.

Yet both Yakima and Okanagon have a higher incidence of  $A_1$  than do the Coastal Swinomish, or the other Northwest Coast tribes. To me this suggests that the gene for  $A_1$  reached them both from the east. Other Sahaptin tribes live east of the Yakima, and other Salish live east and northeast of the Okanagon. Beyond them are the Blood and the Blackfoot, long

TABLE 4  
*The Duffy system*

	PHENOTYPE DISTRIBUTION		GENE FREQUENCIES	
	Fy (a+)	Fy (a-)	Fy <sup>a</sup>	Fy <sup>b</sup>
Yakima 97	76	21	.54	.46
Mixed	5	1		
Doubtful	11	4		
Indian	60	16	.54	.46
Sarcee 89	82	7	.72	.28
Bood 235	220	15	.75	.25
Blackfoot 39	38	1	.84	.16
Stoney 155	137	18	.66	.34
Cree 165	155	10	.75	.25
Chippewa 161	158	3	.86	.14
Diegueño 58	52	6	.68	.32

known to have an almost uniquely high incidence of  $A_1$  (Matson and Schrader, '33; Chown and Lewis, '53). The native Indian source of gene  $A_1$ , and the direction of gene-flow, both seem reasonably clear.

The distinctiveness of the Yakima, so evident in the MN and the RH systems, is also shown in the case of the Duffy factor. Although we do not, as yet, have data to compare them with any Salish group, figures from other Indian tribes have been published, and indicate that the Yakima have the highest incidence of Fy<sup>b</sup> yet reported from North America. This is shown in table 4. Although very scattered, these com-

parative figures suggest that the West Coast may be the center of distribuion of this gene among native Americans.

#### CONCLUSIONS

Are linguistic barriers against gene-flow as strong as geographical barriers, or as the barrier of a difference in basic culture type? In this particular case, at any rate, the linguistic barrier would appear to be the stronger. The Okanagon differ from the Yakima in the MN system of blood groups. They differ even more markedly in the RH system. The Okanagon differ much less, in either system, from the Swinomish, despite paucity of contact between these two tribes in recent centuries. The two Plateau groups resemble one another in the ABO system, but this can be most readily explained by contacts in each case with more easterly tribes of its own linguistic stock, rather than by interbreeding between them.

Whether or not this particular case may be taken as typical of all such cases is quite a different matter. Certainly the gene frequency of O, among the Swinomish, has been raised by the considerable degree of intermarriage between the Nootka and all the Coast Salish peoples — a good example of the breaking of linguistic barriers to gene-flow. We have, however, especially due to the excellent work of Chown and Lewis in Canada (Chown, '53, '55, '56), other evidence worth considering. The very high percentage of A<sub>1</sub>, found among the Blood and the Blackfoot, does not appear to have spread at all to the east, and only to a relatively small degree to their western neighbors, such as the Flathead. Their dependent neighbors, the Athapaskan Sarcee, on the contrary, do appear to have acquired some A genes from the Blood.

Athapaskan tribes in general, however, appear to have a higher gene frequency of A than do most American Indians. This is true of the Navajo in the Southwest, as compared to such tribes as Pueblo (Allen '35) or Pima (Hanna, '53), and of Canadian Athapaskans also. At the same time, the Athapaskan gene frequency of N is consistently less than that of neighboring tribes, whether in Canada or the Southwest

(Allen, '37). To these two distinctions, the Athapaskans add a third: great diversity of RH types. Carrier, Sarcee, and Navajo (Boyd, '49) all show this, in contrast to the almost total absence of any genes but  $R_1$ ,  $R_2$ , and  $R_z$  among other American Indians. It would appear that the Athapaskans had mated very little with their neighbors.

In simply organized bands of hunting-fishing-gathering peoples, intra-tribal marriages must serve to strengthen social solidarity. The more fortunate tribes may increase in numbers and spread over large areas, scaling mountains and crossing deserts, as both Salishans and Athapaskans have, without much genetic contact with other groups. In areas where inherited status becomes important, however, the search for prestige may well overcome the convenience of intra-tribal marriage. If mates from another tribe, even a tribe of a different linguistic stock, can bring social advantages, the language barrier to gene-flow will certainly be scaled with greater ease than any mountain range.

## LITERATURE CITED

- ALLEN, F. W., AND W. SCHAEFFER 1935 The distribution of the human blood groups among the Navajo and Pueblo Indians of the Southwest. Univ. of New Mexico Bulletin, 4: 1-29.
- ALLEN, F. W., AND H. LARSEN 1937 Heredity of agglutinogens M and N among Pueblo and Blackfoot Indians. J. Immunology, 32 (4): 301-305.
- BOYD, W. C. 1939 Blood groups. Tabulae Biologicae, 18, part 2, 113-240.
- BOYD, W. C., AND L. G. BOYD 1949 The blood groups and types of the Ramah Navajo. AJPA, 7 (4): 569-575.
- BRUES, A. M. 1954 Selection and polymorphism in the ABO blood groups. AJPA, 12 (4): 559-598.
- CHOWN, B., AND M. LEWIS 1953 The ABO, MNSs, P, RH, Lutheran, Kell, Lewis, Duffy and Kidd blood groups and the secretor status of the Blackfoot Indians of Alberta, Canada. AJPA, 11 (3): 369-383.
- 1955 The blood-groups and secretor genes of the Stoney and Sarcee Indians of Alberta, Canada. AJPA, 13 (2): 181-190.
- 1956 The blood-group genes of the Cree Indians and the Eskimos of the Ungava district of Canada. AJPA, 14 (2): 215-224.
- HANNA, B. L., A. DAHLBERT AND H. STRANDSKOV 1953 A preliminary study of the population history of the Pima Indians. Am. J. of Human Genetics, 5 (5): 377-388.
- HULSE, F. S. 1955 Blood types and mating patterns among Northwest Coast Indians. SWJA, 11 (2): 93-104.



- MATSON, G. A., AND H. F. SCHRADER 1933 Blood grouping among "Blackfeet" and "Blood" tribes of American Indians. *J. Immunology*, 25 (2): 155-163.
- MATSON, G. A., AND C. L. PIPER 1947 Distribution of the blood groups M-N and RH types among the Ute Indians of Utah. *AJPA*, 5 (3): 357-368.
- MATSON, G. A., E. KOCH AND P. LEVINE 1954 A study of the hereditary blood factors among the Chippewa Indians of Minnesota. *AJPA*, 12 (3): 413-426.
- McCONNELL, R. B. 1956 Selection and the ABO Group Locus. *Annals of New York Academy of Science*, 65 (1): 12-25.
- MOURANT, A. E. 1954 *The Distribution of the Human Blood Groups*. Blackwell. Oxford.
- PANTIN, A. M., AND R. KALLSEN 1953 The blood groups of the Diegueño Indians. *AJPA*, 11 (1): 91-96.
- SWADESH, M. 1950 Salish internal relationships. *Int. J. of Am. Linguistics*, 16 (4): 157-167.

# CHANGE IN THE PROFILE OF THE OSSEOUS CHIN DURING CHILDHOOD

HOWARD V. MEREDITH

*Iowa Child Welfare Research Station, State University of Iowa  
Iowa City, Iowa*

THREE FIGURES

## INTRODUCTION

This paper adds to knowledge on the ontogeny of the human chin. The need for further research on this topic is revealed in a recent monograph by DuBrul and Sicher ('54) entitled, *The Adaptive Chin*. While an extensive body of information relating to the phylogeny of the chin is synthesized in *The Adaptive Chin*, reference to ontogenetic modification is meagre. To wit: "... the ontogenetic development of man is characterized by the emergence of the chin . . ." and "... marked projection of the chin eminence is not seen in the newborn . . ."

The present report<sup>1</sup> is based on longitudinal records that span one decade of postnatal life. Its data pertain to the anterior profile of the mandible. The data are analysed for variability at three childhood ages (4 years, 9 years, and 14 years) and for amount of change during the interval between age 4 years and age 14 years.

## MATERIALS AND METHODS

Collection of the source materials took place 1946-56. The subjects were 34 American-born white children of northwest European ancestry and above average in socioeconomic status.

<sup>1</sup>Supported in part by a research grant, D-217, from the National Institute for Dental Research, of the National Institutes of Health, Public Health Service.

A *norma lateralis* roentgenogram of each subject's head was obtained at ages 4, 9, and 14 years. The exposures were made with the head maintained in a positioner (Higley, '36), the film paralleling the midsagittal plane and near the side of the head, the distance from the x-ray source to the midsagittal plane held constant at 150 cm, and the central x-ray passing through the acoustic meatuses.

Each roentgenogram was prepared for study by determining the line lying in the mandibular plane and orienting this horizontally (see fig. 1, line XY). Two points along the ante-

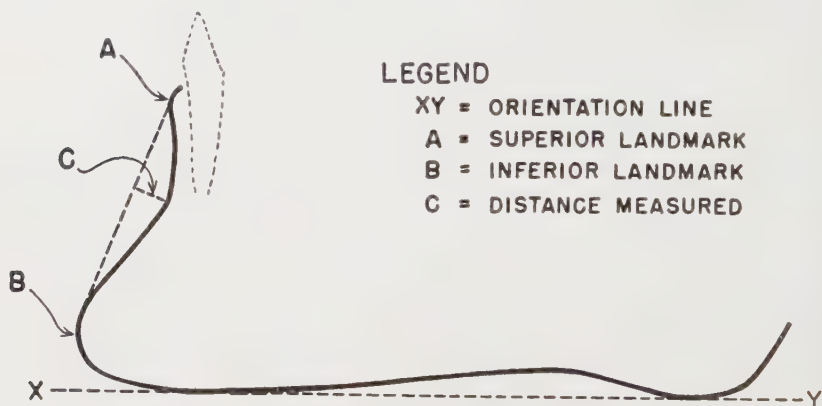


Fig. 1 Graphic representation of the method.

rior margin of the mandibular shadow were located with the aid of a magnifying glass, and pricked with a needle probe. The superior point, A, was the most anterior projection of the mandibular shadow in the alveolar region. The inferior point, B, was the most anterior projection of the entire mandibular shadow. A straight line was drawn connecting these two points. The measurement determined, C, was the *maximum perpendicular distance* from line AB to the anterior margin of the mandibular shadow.

Two anthropometrists worked together in locating the points. Each proceeded independently in measuring the greatest rectilinear distance at right angles with line AB. By

averaging the paired records and correcting the resulting values for roentgenographic enlargement (see Newman and Meredith, '56), highly valid measures were obtained symbolizing, in metric terms, anatomic variation in the anterior concavity of the mandibular profile.

# FINDINGS

Table 1 presents the results from analysis of the measures. It will be seen:

TABLE 1

*A measure of the anterior concavity of the mandible on 34 American-born white children (see fig. 1 and text). Unit: Millimeters*

	BOYS (14)	GIRLS (20)	BOTH SEXES
Mean:			
4 years	0.8	0.9	0.8
9 years	1.6	1.7	1.6
14 years	2.5	2.5	2.5
Minimum:			
4 years	0.2	0.3	0.2
9 years	1.1	1.0	1.0
14 years	1.7	1.7	1.7
Maximum:			
4 years	1.4	1.6	1.6
9 years	2.3	2.6	2.6
14 years	3.3	3.3	3.3
Change 4-14 years:			
Minimum	0.8	0.6	0.6
Mean	1.7	1.6	1.7
Maximum	2.6	2.6	2.6

1. Sex differences are insignificant; corresponding statistics in the columns for boys and girls are similar throughout.

2. The composite means for children of both sexes increase from 0.8 mm at age 4 years, through 1.6 mm at age 9 years, to 2.5 mm at age 14 years. Mandibles representing these averages are depicted in the middle column of figure 2.

3. At one end of the distribution of mandibular profiles for age 4 years, there is almost no anterior concavity. This is

shown by the minimum value of 0.2 mm in table 1, and by the tracing at the upper left of figure 2.

4. The maximum expression of anterior concavity ("incurvatio mandibularis'') is markedly less among children 4 years of age than among children 14 years of age. Metric and graphic support for this generalization appears in rows 7 and 9 of table 1, and in the right hand column of figure 2.

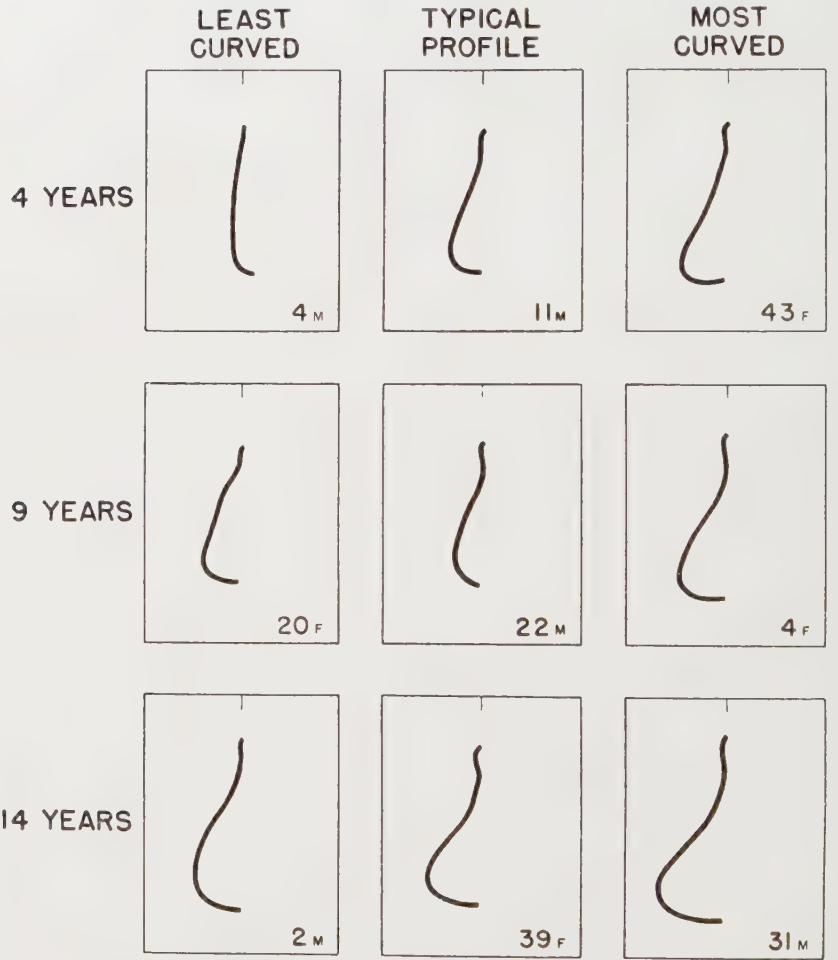


Fig. 2 Anterior profile of mandible. Each tracing positioned with the mandibular plane paralleling the base line.



5. Change in the curvature of the anterior profile of the mandible during the postnatal decade 4 to 14 years (a) is found for every child studied and (b) is much greater for some individuals than others. Change distributions, derived by subtracting each child's measurement at age 4 years from his measurement at age 14 years, are characterized in the last three rows of table 1. The maximum change of 2.6 mm is por-

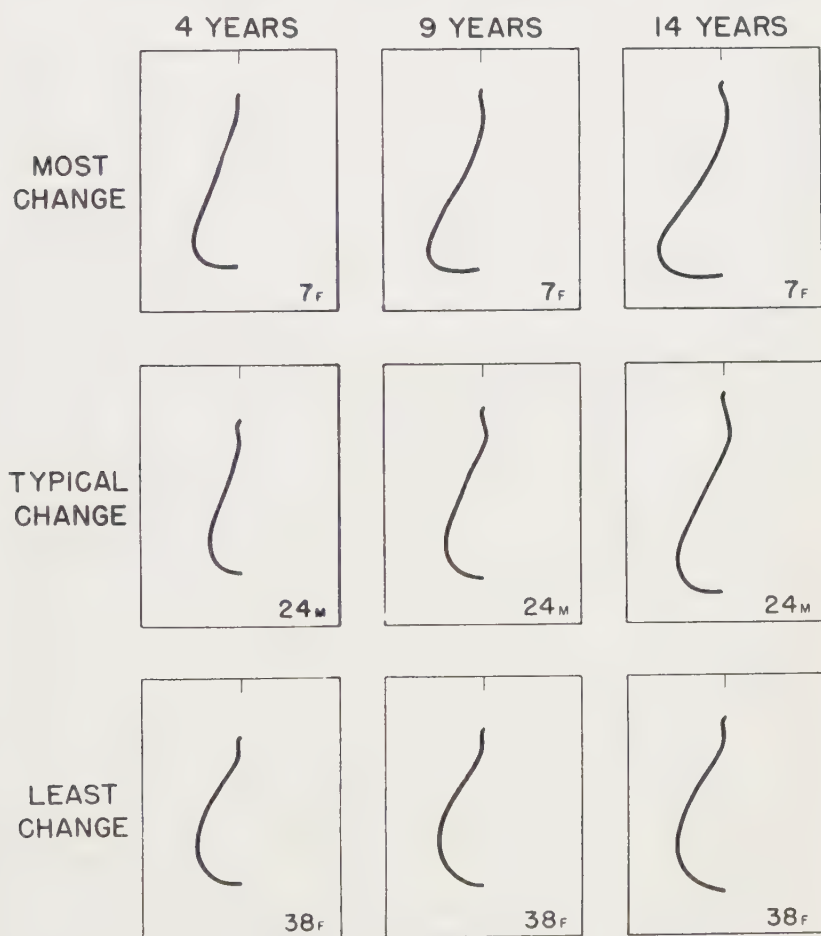


Fig. 3 Anterior profile of mandible. Each tracing positioned with the mandibular plane paralleling the base line.

trayed by the top group of profile tracings in figure 3. Tracings for the mandible exhibiting the least change are displayed along the bottom of figure 3.

#### SUMMARY

The materials studied are *norma lateralis* roentgenograms obtained on 34 American-born white children at the postnatal ages 4 years, 9 years, and 14 years. A quantitative method is devised for representing variation in the concavity of the anterior margin of the mandibular shadow. Application of this method shows that during the decade investigated there is a progressive increase in anterior concavity of the mandible. Individual differences are illustrated with respect to profile of the osseous chin at selected ages, and change in chin profile over the ten-year period of human ontogeny encompassed.

#### LITERATURE CITED

- DUBRUL, E. L., AND H. SICHER 1954 The Adaptive Chin. Charles C Thomas, Springfield, Illinois.
- HIGLEY, L. B. 1936 Head positioner for scientific radiographic and photographic purposes. *Internat. J. Orthodontia*, 22: 699-704.
- NEWMAN, K. J., AND H. V. MEREDITH 1956 Individual growth in skeletal bi-gonial diameter during the childhood period from 5 to 11 years of age. *Am. J. Anat.*, 99: 157-187.

## STRATIGRAPHICAL AGE OF THE SWANSCOMBE SKULL

KENNETH P. OAKLEY

*British Museum (Natural History), London*

From time to time the question is raised as to whether the Swanscombe Skull is of Second or Third Interglacial age. Although now widely accepted as dating from the Second (so-called Great) Interglacial, the possibility of its being of Third (Last) Interglacial age is I believe worth a critical re-examination at this time.

First I think it must be admitted that the universal use of the alpine terminology of Penck and Brückner may have led us astray. In so far as Swiss geologists are still disputing whether certain moraines in the Alps are "Jungriss" or Würm I (Zeuner, '54, p. 104) we may find that we are fighting a battle on shifting ground if we see our problem as a question of whether the Swanscombe Middle Gravels are younger or older than particular moraines in the Alps. Let us look at the problem from another angle.

It is true that the climatic fluctuations of the Pleistocene period, resulting in the periodic advances of glaciers, culminated in the higher latitudes with the formation of continental ice sheets on 4 occasions. However, where we have a continuous record of major and minor climatic oscillations, for example in the Atlantic ocean-bottom cores, the four-fold glacial subdivision of the Pleistocene is far from clear. Local factors probably modified the rate of advance and recession of glaciers to such an extent that in some parts of the northern hemisphere one or more glacial "climaxes" were suppressed, while in other regions the stadia of a single "climax" ap-

peared as pronounced as two or more separate "climax" glaciations. In the latter case water-laid deposits between two tills or solifluxion layers are not necessarily interglacial. To some extent the problem of Pleistocene correlation resolves itself into distinguishing true interglacials from interstadials, and separating one interglacial from another.

The interglacials were of longer duration than the interstadials and for the most part associated with high sea-levels (either rising or falling); and in North-west Europe at any rate they generally included a phase of climate warmer than that characterising the same area today. During the relatively shorter interstadials on the other hand, the sea-level was relatively low, and the climate remained cool.

Three main interglacials have been recognized in Britain: Cromerian, Hoxnian and Ipswichian (West, '56), corresponding to the Antepenultimate, Penultimate and Last Interglacials of Zeuner as these terms are applied by him in Britain. The typical deposits of the three interglacials, which were established on the basis of pollen-diagrams, are the Cromer Forest Bed, the Hoxne Lake-beds and the Bobbit's-Hole Beds in the Ipswich region. Since all three series include a climate phase warmer than that of the present time, they are accepted as representing full interglacials. The sequence of vegetation marking a cycle of climatic phases was similar in all interglacials; but in detail, and when the relative abundance of the various plant species is considered phase by phase, each interglacial proves to have certain distinctive features. Judged by their pollen-diagrams the Hoxnian and Ipswichian interglacials correspond precisely with the Needian (Holsteinian) and Eemian stages of the North German-Netherlands sequence, both of which were marked by marine transgressions.

The Swanscombe river gravels contain glacial erratics derived from the outwash or till of a preceding glaciation, and they are succeeded by solifluxion deposits indicating a return of intensely cold (periglacial) conditions. They contain a temperate fauna, including "*Elephas*" *antiquus* and "*Rhi-*

*noceros mercki*." These facts indicate that the gravels were laid down either during an interglacial or just conceivably during an interstadial. We shall see that as they were associated with high sea-level it is only reasonable to attribute them to an interglacial.

No pollen has been found in the Swanscombe deposits, but on the score of several other lines of evidence it appears impossible to place the Middle Gravels of Swanscombe in any interglacial stage other than the Hoxnian.

They can clearly be excluded from the Cromerian on the faunal evidence, while to place them in the Ipswichian (Eemian) would do violence to the archaeological facts, for it would imply that the Hoxne Acheulian industry is earlier than the Swanscombe Acheulian. The hand-axe industry of Swanscombe was originally described as transitional from Chelles to St. Acheul I (Smith and Dewey, '13, p. 189). It is certainly no more advanced technically than that of Hoxne, which, as McBurney ('55) has shown, is closely comparable with the industry of the *Atelier de Commont* in the 30-m terrace of the Somme. At one time it was believed that Early or Proto-Levalloisian artifacts occurred in the Swanscombe Middle Gravels, but Mr. J. Wymer's unpublished analysis of the large quantities of flakes recently recovered from these deposits finds no support for this idea, which arose through misinterpretation of the small percentage of waste-flakes that in this, as in any hand-axe industry, are of Levalloisoid type.<sup>1</sup> The Swanscombe hand-axe industry was regarded in 1938 as Middle Acheulian (Hawkes *et al.*, '38). No new facts have emerged to alter this diagnosis. To regard the Swanscombe gravels as Eemian would also involve referring the succeeding Taplow-Crayford series of deposits, with their Levalloisian industries and *Corbicula* shell-bed, to interstadial phases of the Last Glaciation. It is true that the suggestion has been advanced (King and Oakley, '44) that the Baker's

<sup>1</sup> Similarly, flakes from the Hoxne interglacial deposits were formerly regarded as "Mousterian" but this identification too has been shown by McBurney to be erroneous.



Hole Levalloisian industry, generally regarded as at the base of this series, should be compared with Levalloisian V of the Somme; and this would qualify the overlying Coombe Rock to represent the first stage of the Last Glaciation. However, the discovery that Levallois technique of the Baker's Hole type was being employed by people of Upper Acheulian culture at Le Tillet in the Seine (Bordes, 54, fig. 158 nos. 1,2), suggests that this anomalous Thames Valley industry may after all date from the time of the Third Glaciation.

This is not the place to discuss in any detail the stratigraphy of the Clactonian industries of Britain, but it may be noted in passing that the earliest occurs in the Lower Gravel of Swanscombe, which is separated from the Middle Gravels (with Acheulian) by the sterile Lower Loam. The Clactonian industry of the type-locality (an old channel of the Thames preserved on the shore at Clacton-on-Sea, Essex) is technically more advanced than that of the Swanscombe Lower Gravel (Oakley and Leakey, '38). Until recently the Clacton Channel deposits have generally been regarded as dating from the hiatus represented by the Swanscombe Lower Loam and its weathered surface, and therefore as antedating the Middle Acheulian horizons. West ('56, p. 340) has now tentatively placed the Clacton Channel as later than the hand-axe horizon at Hoxne on the grounds that the *upper* layers of the Clacton channel filling contain pollen of a coniferous phase marking the closing phase of an interglacial. However, if the *lower* layers at Clacton with the typical flint industry cover a long period of time it is quite possible that they do include horizons below that of the Hoxne Acheulian. Whether the type Clactonian is older or younger than the Swanscombe Middle Gravels cannot be settled with the evidence at present available, but fortunately the most important point is clear: both Clacton and Hoxne have pollen-diagrams which can only be duplicated in the Needian (Holsteinian) interglacial deposits of the Continent.

The differences between the mammalian faunas of the Hoxnian and Ipswichian interglacials in Britain have not yet

been studied in detail, but all the available paleontological evidence supports the view that the Swanscombe gravels are older than the Last Interglacial. First we may note that the archaic beaver *Trogotherium* has been recorded both from the Swanscombe<sup>2</sup> and Hoxne deposits (Spencer, '56), and as far as we know it had been completely replaced by *Castor fiber* by Last Interglacial times.

The late Dr. A. Schreuder of Amsterdam examined a series of Microtine mammal teeth from the Swanscombe gravels, and she reported (Schreuder, '50) that they were all extinct species, and included survivors from the Cromerian stage. She also examined a series of vole teeth from the deposits with Tayacian industry at Fontéchevade (Charente). Her final report has not yet been published, but in March 1950 she wrote to say that so far she had failed to find any extinct species among a fairly large collection from Fontéchevade. The fauna of the Fontéchevade deposits includes "*Rhinoceros mercki*," *Dama dama*, *Castor fiber* and *Emys*, and is therefore evidently interglacial. The marked contrast between the Microtine fauna of the Swanscombe gravels and that of Fontéchevade would be extremely difficult to explain if they both belonged to the same interglacial. On the contrary the difference is easily accounted for if the Swanscombe gravels antedate the Third Glaciation, while the Fontéchevade layers post-date it, for it was during that glaciation that the modern species of Microtinae multiplied and spread widely. On the basis of Schreuder's identification of the cold-loving lemming (*Lemmus*) in an otherwise typically interglacial assemblage in the Upper Middle Gravel of Swanscombe, I have suggested that this layer might be contemporary with the onset further

<sup>2</sup> There is still some doubt as to whether the Shell Bed of Ingress Vale which yielded the canine tooth of *Trogotherium* belongs to the Lower Gravel or the Middle Gravel; Acheulian ovate hand-axes were embedded in it, but this has been explained as being the result of overlying layers looping down into an older shell-bed through "piping" or collapse. On the other hand the Ingress Vale Shell-bed may belong to a Late Middle Acheulian horizon, and equate precisely with Hoxne.

north (and in the Alps) of cooler conditions leading to the Third Glaciation. If so, the Middle Gravels possibly belonged to the early part of the Drenthian stage succeeding the Needian of the Netherlands (Oakley, '52, p. 289). This correlation seemed to be supported by the finding of *Microtus ratticepoides* in the Swanscombe Middle Gravels and in the Drenthian deposits. However, the evidence was no more than suggestive, and now that West's findings at Hoxne indicate that the Acheulian horizon there considerably antedated the closing stages of the Needian interglacial, it has become more probable that the Swanscombe Middle Gravels belong to that stage rather than to the Drenthian.

It is worth noting that the fauna of the Lower and Middle Gravels of Swanscombe includes the extinct fallow deer *Dama clactoniana*, which was first described from the Clacton Channel deposits. The records of reindeer antler from the Ingress Vale Pit, Swanscombe, were based on an early misidentification of fragmentary antlers of *Dama clactoniana* (Oakley, '52, p. 290, footnote). All the remains of fallow-deer in European deposits of undoubtedly Last Interglacial age appear to be indistinguishable from *Dama dama*.

Our reference of the Swanscombe Middle Gravel to the Second or Hoxnian interglacial assumes that there is no possibility of their belonging to an interstadial of the Third Glaciation. The palaeontological evidence did not entirely rule that out, for as the author (Oakley, '52) has shown the fauna of the Middle Gravels might be an Atlantic equivalent of the Drenthian fauna of the continent. However, the relation of these gravels to a high sea-level is now regarded as completely ruling out the possibility of their being interstadial.

The Swanscombe gravels are about 35 feet thick, indicating a rise of sea-level during their deposition. They form part of the 100-ft. terrace of the Thames which maintains a remarkably level surface for nearly 50 miles in a part of Britain which has been tectonically stable since Tertiary times. As pointed out by Zeuner ('45, p. 114) upstream of Swan-

scombe the gradient of the terrace over a stretch of 13 miles is less than three inches per mile. This indicates that the neck of the estuary was not more than 15 miles downstream from Swanscombe when the gravels were being accumulated. As they attain a height of 110 feet above present river level it is estimated that at the termination of the Middle Gravels aggradation the Thames was graded to a sea-level with high-water mark around 107 feet above O.D., which agrees closely with the 32 m sea-level of the Great Interglacial, the so-called Tyrrhenian stage of Depéret's Mediterranean sequence.<sup>3</sup> The succeeding Taplow terrace of the Thames is graded to an estuarine level of about 60 feet above O.D., corresponding to the Main Monastirian (18 m) sea-level of the Last Interglacial.

In conclusion we can find no escape from having to refer the Swanscombe Middle Gravels — the horizon of the Swanscombe skull — to the Hoxnian interglacial; and to regard this as Last Interglacial rather than Great Interglacial would involve discrediting all the lines of evidence that are at present considered valid by Pleistocene stratigraphers.

The interglacial and interstadial sequence in N. W. Europe particularly in Britain, may be more complicated than we think. Certainly there are difficulties to be overcome before all the known deposits can be comfortably accommodated. For instance: are the Early Acheulian gravels of Hanborough and Caversham to be referred to a late stage of the Cromerian, or to an unrecognized interstadial between two phases of the Second Glaciation or to an early stage of the Hoxnian interglacial? We do not yet know, but the main arguments that have been advanced above in favour of referring the Swanscombe Middle Gravels, or Late Boyn Hill Terrace, to the Hoxnian interglacial are unaffected by the unresolved doubts regarding the stratigraphic position of other terrace deposits in the Thames Valley.

<sup>3</sup> Tyrrhenian I of those authors who use the term Tyrrhenian II in place of Main Monastirian.



## LITERATURE CITED

- BORDES, F. 1954 Les limons quaternaires du Bassin de la Seine. *Arch. Inst. Pal. Humaine, Mém.*, 26: (esp. pp. 357-369).
- DINES, H. G., ET ALIA. 1938 A general account of the 100-ft. Terrace Gravels of the Barnfield Pit, Swanscombe. *J. Roy. Anthrop. Inst.*, 78: 21-27.
- HAWKES, C. F. C., ET ALIA. 1938 The industries of the Swanscombe Pit. *J. Roy. Anthrop. Inst.*, 78: 30-47.
- KING, W. B. R., AND K. P. OAKLEY 1944 The age of the Baker's Hole Coombe Rock, Northfleet, Kent. *Nature*, 155: 51.
- MCBURNY, C. M. B. 1955 In *West and McBurney*, pp. 139-154.
- OAKLEY, K. P. 1938 Correlation of the deposits of the Barnfield Pit. *J. Roy. Anthrop. Inst.*, 78: 55-58.
- 1952 Swanscombe Man. *Proc. Geol. Assoc.*, 63: 271-300. Reprinted, 1953, in *Ybk. Phys. Anthrop.*, 8: (for 1952) 40-70. (Full list of references to literature on Swanscombe.)
- OAKLEY, K. P., AND M. LEAKEY 1938 Report on the excavations at Jaywick Sands, Essex (1934), with some observations on the Clactonian Industry and on the fauna and geological significance of the Clacton Channel. *Proc. Prehist. Soc. N.S.*, 3: (1937), 217-260.
- SCHREUDER, A. 1950 Microtinae from the Middle Gravels of Swanscombe. *Ann. and Mag. Nat. Hist.*, ser. 12, 3: 629-635.
- SMITH, R. A., AND H. DEWEY 1913 Stratification at Swanscombe. *Archaeologia*, 64: 177-204.
- SPENCER, H. E. P. 1956 The Hoxne mammalian remains. *Phil. Trans. Roy. Soc. Lond. (B)*, 239: 354.
- WEST, R. G. 1955 The Glaciations and Interglacials of East Anglia. *Quaternaria*, 2: 45-52.
- 1956 The Quaternary deposits at Hoxne, Suffolk. *Phil. Trans. Roy. Soc. Lond. (B)*, 239: 265-356.
- WEST, R. G., AND C. M. B. MCBURNY 1955 The Quaternary deposits at Hoxne, Suffolk, and their Archaeology. *Proc. Prehist. Soc. N.S.*, 20: (1954), 131-154.
- ZEUNER, F. E. 1945 The Pleistocene Period. *Ray Society, London.* (Esp. pp. 114-116.)
- 1954 Riss or Würm? *Eiszeit u. Gegenw.*, Bd. 4/5, S. 98-105.



# ERUPTION OF PRIMARY TEETH IN KOREAN RURAL CHILDREN

DUK JIN YUN

*Institute for Rural Health, Kaijung-Myon, Okku-Gun,  
Chulla-Book-Do, Korea*

## INTRODUCTION

The eruption of primary teeth is an important index to the development of infants and children. This investigation was carried out during the early part of May in both 1953 and 1954, a period in Korea that was designated as "Babies and Mothers Days." The primary teeth of the infants and children living in a rural area in the Korean province of Chulla-Book-Do, in the big villages of Okku-Gun, Ikksan-Gun, Kimje-Gun, and Jungoop-Gun were examined. This area is approximately 25 miles in diameter and a large number of children were available during the usual health examinations.

## MATERIAL AND METHODS

The observations were made on appointed days in a number of dispensaries which belong to the Institute for Rural Health in Korea. One dispensary is situated in each Gun (County). The number of individuals examined was 1,838 within an age range of three months to 36 months. All of the children were presumably normal and healthy and showed no acute or chronic diseases. The birth dates were given by the parents accompanying the children. The dental examinations were made by the author. As each child took his place in front of the examiner, an assistant noted the result of the examination. Each examination was made with the aid of a dental mirror. The data were recorded on cards that contained the following:

*Primary Teeth*

	Upper											
Right	V	IV	III	II	I	/	I	II	III	IV	V	Left
Side	V	IV	III	II	I	/	I	II	III	IV	V	Side
	Lower											

proximate age group showing the 40-60 percentile eruption rate was 9-11 months.

*C. Lateral incisors.* These teeth erupted third in order. Mandibular lateral incisors started to erupt a little earlier than the maxillary lateral incisors, however, the difference in general was very small. The approximate age showing 30-70 percent eruption of the lateral incisors was in 11 to 14 months age group.

TABLE 1

*Eruption of central, lateral incisors and cuspids*

AGE	NO. EXAM- INED	PER CENT CHILDREN WITH TEETH ERUPTED											
		Mandibular central incisors		Maxillary central incisors		Mandibular lateral incisors		Maxillary lateral incisors		Mandibular cuspids		Maxillary cuspids	
<i>months</i>		%	<i>S.E.</i>	%	<i>S.E.</i>	%	<i>S.E.</i>	%	<i>S.E.</i>	%	<i>S.E.</i>	%	<i>S.E.</i> <sup>1</sup>
3	70	3	2.0										
4	60	12	4.0	4	2.4								
5	63	16	4.6	10	3.8	2	1.8						
6	82	24	4.7	10	3.1	6	2.7						
7	77	43	5.6	20	4.6	13	3.8						
8	60	53	6.4	28	5.8	10	3.9	5	2.8				
9	48	58	7.1	35	6.7	16	5.3	21	5.9				
10	46	70	6.8	55	7.3	16	5.4	31	6.8	4	2.9	4	2.9
11	40	83	5.9	71	7.2	31	7.3	40	7.7	17	5.9	17	5.9
12	40	80	6.3	81	6.2	39	7.7	44	7.8	13	5.3	13	5.3
13	37	95	3.6	90	4.9	64	7.9	63	7.9	21	6.7	23	6.9
14	53			93	3.5	80	5.5	86	4.8	28	6.1	30	6.3
15	58					83	4.9	89	4.1	40	6.4	42	6.5
16	58					95	2.9	98	1.8	47	6.6	50	6.6
17	67									57	6.0	58	6.0
18	58									55	6.6	60	6.4
19	56									58	6.6	57	6.6
20	52									75	6.0	73	6.2
21	48									85	5.1	88	4.7
22	68									88	3.9	90	3.6

<sup>1</sup> The standard error of percentages is  $\sqrt{\frac{p \times q}{n}}$  where p is the percentage of individuals belonging to one category (i.e. erupted). q is the percentage in the other category (i.e. not erupted), and n is the number of individuals in the sample.

*D. Cuspids.* Table 1 shows that there was very little difference between the eruption rate of the maxillary cuspids and the mandibular cuspids. At the age of 10 months, only 4% of the children examined had the cuspids erupted, while at 22 months, 88-90% of the children had their cuspids erupted. In the 40-60 percent group the maxillary and mandibular cuspids erupted between the ages of 15 to 19 months.

TABLE 2  
*Eruption of first and second molars*

AGE	NO. EXAM- INED	MANDIBULAR FIRST MOLARS		MAXILLARY FIRST MOLARS		MANDIBULAR SECOND MOLARS		MAXILLARY SECOND MOLARS	
<i>months</i>		%	<i>S.E.</i>	%	<i>S.E.</i>	%	<i>S.E.</i>	%	<i>S.E.</i>
8-9	108	6	2.3	5	2.1				
10-11	86	10	3.2	10	3.2	1	1.1	1	1.1
12-13	77	19	4.5	22	4.7	8	3.1	8	3.1
14-15	111	36	4.6	35	4.5	14	3.3	15	3.4
16-17	125	57	4.4	60	4.4	23	3.8	26	3.9
18-19	114	70	4.3	74	4.1	27	4.2	29	4.2
20-21	100	82	3.8	81	3.9	31	4.6	31	4.6
22-23	121	87	3.0	88	3.0	36	4.4	38	4.4
24-25	133	90	2.6	93	2.2	58	4.3	55	4.3
26-27	122	96	1.8	95	2.0	70	4.1	65	4.3
28-29	89					80	4.3	79	4.3
30-31	95					88	3.3	86	3.6
32-33	99					87	3.4	87	3.4
34-35	106					91	2.8	90	2.9

*E. First molars.* Very little difference was observed between the eruption of the maxillary and mandibular first molars (table 2). The approximate age group with a 30-70% eruption rate was from 13 to 19 months.

*F. Second molars.* Again, very little difference was noted between mandibular and maxillary second molars. The age showing 30-70% eruption occurred in the 19 to 29 months group.

## II. Order of eruption

The order of eruption was summarized from tables 1 and 2 as follows:

TABLE 3

*Eruption of primary teeth in 1,838 Korean children*

	<i>Maxillary</i>	<i>Mandibular</i>
Central Incisors	9-11 months	7-9 months
Lateral Incisors	11-14 months	11-14 months
Cuspids	15-19 months	15-19 months
First Molars	13-19 months	13-19 months
Second Molars	19-29 months	19-29 months

TABLE 4

*The order of eruption of primary teeth in 1,838 Korean children*

	2	3-4	7-8	5-6	9-10
/	I	II	III	IV	V
	I	II	III	IV	V
	1	3-4	7-8	5-6	9-10

The order of eruption in Korean children is similar to that of American children and Japanese children except that the mandibular lateral incisors and cuspids erupted earlier than maxillary ones in American children, while at the same time in Korean children.

### DISCUSSION

According to the numerous investigations performed thus far, the relationship between the eruption of deciduous teeth and age appears to have a strong genetic predetermination. Tooth eruption may be greatly delayed, however, by nutritional disturbances and by other conditions which inhibit growth in general. It has been said that internal and external environmental factors unquestionably play an important part in tooth structure and eruption. For example, maternal health and diet may exert considerable influence upon the development of the primary teeth (13). Evidence has been cited that indicates that lack of vitamins A, D, of calcium and ascorbic



acid interfere with normal tooth development in fairly characteristic ways.

Ninety-five to 96% of Korean rural babies are breast fed, and babies are not weaned completely from breast milk until the age of 8 to 12 months, however, boiled rice in addition to breast milk is begun in the eighth month. Of course they are not on any extra vitamins A, D, and C in any

TABLE 5

*Eruption of primary teeth (Comparison of Korean, American, and Japanese infants). (9, 10,)*

	KOREAN	MAXILLARY AMERICAN	JAPANESE	KOREAN	MANDIBULAR AMERICAN	JAPANESE
Central Incisors	9-11 months	6-9 months	7-9 months	7-9 months	5-7 months	7-9 months
Lateral Incisors	11-14 months	7-11 months	8-11 months	11-14 months	6-8 months	8-11 months
Cuspids	15-19 months	16-20 months	17-20 months	15-19 months	14-18 months	16-19 months
First Molars	13-19 months	10-18 months	15-20 months	13-19 months	8-16 months	15-20 months
Second Molars	19-29 months	20-28 months	23-36 months	19-29 months	16-24 months	22-26 months

period except for the time showing some symptoms of those deficiencies. There is no definite weaning period and breast milk may be continued until the mother's milk supply has been exhausted (16). The average weaning period in Korean rural area is 2 years and 3 months, however, when they become two years old they eat everything which adults eat in addition to the mother's milk.

It is interesting to note that the eruption of primary teeth in normal Korean rural children differs slightly from that usually accepted for American and Japanese children. The order of eruption of primary teeth is similar to that in American and Japanese children. When one compares the status of eruption of the primary teeth in Korean and

American babies, the teeth erupted in the early months, such as the central incisors, lateral incisors, and first molars, appear two to three months later in Korean infants. In contrast, those that erupt in later months, such as the cuspids and second molars, erupt at the same time in both Korean and American infants.

If one compares these results with those obtained for Japanese infants, the anterior teeth erupt later in Korean infants than in Japanese infants, while the posterior teeth erupt either at the same time in both Korean and Japanese babies, or slightly earlier in Korean infants. Why this is true is not easy to determine at this time, but from the large number of children examined, it seems to be a valid finding.

#### SUMMARY

The time and order of eruption of the primary teeth were determined from the dental examination of 1,838 Korean rural children aged 3 to 36 months. The important findings were:

1. The anterior teeth erupted at a later age among Korean children compared to American and Japanese children.
2. The posterior teeth erupted among Korean children at about the same age as in American children, but an earlier age as compared with Japanese children.
3. The order of eruption of the primary teeth was essentially the same in Korean, American and Japanese children. The exception was that while the mandibular lateral incisors and cuspids erupted among Korean children at about the same age as their maxillary mates; among American children, the mandibular lateral incisors and cuspids erupt earlier than the corresponding teeth on the maxilla.

#### ACKNOWLEDGMENTS

I am indebted to Dr. Harry A. Waisman, Associate Professor of Pediatrics, University Hospital, Madison, Wisconsin, to Dr. Maury Massler, Professor of Department of Pedodontics,

University of Illinois, College of Dentistry, Chicago, Illinois, to Dr. Albert A. Dahlberg, Department of Anthropology, the University of Chicago, Chicago, Illinois and to Dr. Margaret Merrell, Associate Professor of Department of Biostatistics, School of Hygiene and Public Health, the Johns Hopkins University for kindly reviewing this article.

## LITERATURE CITED

- BURMAN, L. 1944 Dentition of identical twins. *J. Am. Dent. Ass.*, 31: 1.
- FRIEL, E. SH. 1922 The effect of the war diet on the teeth and jaws of the children of Vienna. *Int. J. Orth.*, 8: No. 9, 539-572.
- GRIEVES, C. J. 1922 A preliminary study of gross maxillary and dental defects in 300 rats on defective and deficient diet. *J. A. D. A.*, 9: 467-497.
- GUTMAN, B. A. 1939 An adequate calcium and phosphorus regime. *Am. J. Orth.*, and *Oral Surgery*, 25: No. 1, 711-723.
- HANKE, M. T. 1931 Nutrition and dental disorders. *Dental Survey*, June and July.
- HATFIELD, H. K. 1919 A preliminary study of the effect of rickets on the jaws. *Int. J. Orth. and Oral Surgery*, 5: No. 7, 368-379.
- HOWE, P. R. 1921 Effect of vitamin deficient diet upon the teeth. *Dent. Cosmos*, 18: 1086.
- 1923 Effect of diet upon the teeth and bones. *J. A. D. A.*, 10: 201.
- KITAMURA, S. 1942 A study on the time and order of eruption of human teeth (in Tokyo, Japan), *Shikwa Gakuho*, 47: 274.
- MASSLER, M., AND SCHOUR, I. 1944 Atlas of the Mouth and Adjacent Parts in Health and Disease. Chicago Bureau of Public Relations of the Dental Association. Plate 2-3.
- MELLANBY, M. 1928 The influence of diet on the structure of the teeth. *Physical Rev.*, 8: 545-577.
- MORGAN, A. F., G. D. HATFIELD AND M. A. TANNER 1926 A comparison of the effect of supplementary feeding of fruits and milk on the growth of children. *Am. J. Dis. Child.*, 32: 839-849.
- NAKAKAWA, ICHIRO 1953 Nutrition in Children. 290-340, Nanko-Do, Tokyo, Japan.
- SAWIN, P. B. 1939 Applications of the principles of heredity to orthodontics. *Am. J. Ortho.*, 25:
- SIMMONDS, N. 1939 Nutritional corrections as an aid in overcoming growth defect in the oral structures. 25: No. 2, 115-123.
- YUN, D. J. Infant and child mortality in Korean rural area (not published yet).

# ISCHIAL CALLOSITIES AS SLEEPING ADAPTATIONS

S. L. WASHBURN

*Department of Anthropology, University of Chicago,  
Chicago, Illinois*

TWO FIGURES

## *Ischial callosities as sleeping adaptations*<sup>1</sup>

The callosities of the Old World monkeys are areas of thickened, specialized skin, closely attached to the ischia.<sup>2</sup> Miller ('45) has described them as "... adaptive characteristics of the Cercopithecidae, associated with their ability to sit upright." There is some variation in the size and form of the callosities, but they are always present in Old World monkeys (Pocock, '25) and never in the New World monkeys (Pocock, '20). Monkeys unquestionably sit on their callosities, and the explanation that they are sitting adaptations has been quite generally accepted. But many kinds of animals sit without developing callosities, and this fact suggests that

<sup>1</sup>A grant from the Wenner-Gren Foundation for Anthropological Research made possible my investigations on the behavior and anatomy of baboons. I was greatly aided by Dr. J. Desmond Clark, Director of the Rhodes-Livingstone Museum, J. C. Tebbit of the Victoria Falls National Park, I. Miller of the Robbins Camp of the Wankie Game Reserve, and B. L. Mitchell, the Provincial Game Officer who arranged for anatomical specimens. This paper is part of a series on the origin of human behavior written at the Center for Advanced Study in the Behavioral Sciences.

<sup>2</sup>There is a rather widespread confusion between the ischial callosities and sexual skin (Jones, '29, p. 226; Hooton, '31, p. 24; Clark, '34, p. 213). Callosities are cornified, thickened, insensitive, almost avascular areas which are firmly attached to the ischia and are limited to the area of the tuberosities and are present in all Old World monkeys. Sexual skin is sensitive, vascular, and swells periodically in the female, and varies tremendously in its development even among closely related species. Callosities and sexual skin are shown in figure 1.

there is something special about the sitting habits of the Old World monkeys which makes this complicated adaptation necessary.

Recently, I was able to spend many hours watching the behavior of free-ranging baboons in game reserves in Southern Rhodesia, and the following theory on the function of the ischial callosities is based on these observations. Ischial

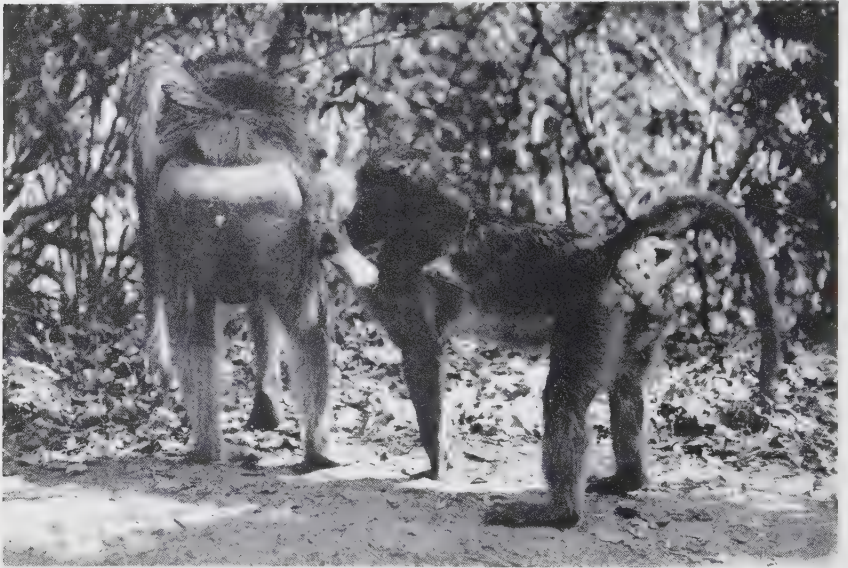


Fig. 1 Adult male and female baboons, showing the large, continuous callosities and adjacent hairless areas in the male and the much smaller callosity and sexual skin in the female.

callosities are sleeping adaptations which enable monkeys to sleep sitting on branches. Baboons were frequently seen napping in this position, as shown in figure 2. At night, baboons sleep in large trees, and on several occasions I watched a troop waking up in the morning. Many of the baboons were seen to be sitting, and no baboons were sleeping lying along the branches. During the daytime, baboons nap sitting in trees, and both sitting and lying on the ground. Clearly, sitting on a rough surface for long periods of time with all the



weight on the ischia would not be possible without the callosities. Careful observation of the sitting posture of baboons shows that it has several special characteristics. These are well shown in figure 2 in which it will be seen that: the hands and feet are close together, the feet are up so that almost all the weight is on the ischia. The animals remain in this position for long periods of time without moving. It is this particular kind of sitting which is related to the presence of callosities.

An attempt was made to check this theory in the Brookfield and Lincoln Park zoos in Chicago. Unfortunately, the behavior of primates is greatly modified by the conditions under which they are kept in zoos. Most cages contain no branches on which a monkey could possibly sleep, and shelves are frequently provided. Even wild baboons often sleep on their sides on the ground when it is safe to do so during the daytime, and this is the usual napping posture in the zoos. However, it is possible to see the special sitting position which I believe to be related to sleeping-sitting. Sitting positions were carefully observed in lorises, lemurs, baboons, macaques, mangabeys, cercopithecus monkeys, langurs, colobus monkeys, several kinds of New World monkeys, gibbons, chimpanzees, gorillas, and orangutans. In a great deal of the behavior which might superficially be called "sitting," the weight is on the feet, and the ischia may even be off the ground. Sitting with the weight on the ischia, the feet off the floor, and hands next to the feet, remaining in this position comfortably and protractedly — this whole complex was seen only in the primates with well-developed ischial callosities, that is, the Old World monkeys and gibbons. In addition, gibbons have a closely similar posture in which they lean back, put one or both arms up, and hold the support against which they are leaning. This posture was observed in the zoo, among wild gibbons in Siam, and it is pictured in Carpenter's account of gibbon behavior (Carpenter, '40, pp. 64, 71, 91, 140, and especially 72). It should be stressed that



Fig. 2 Baboon napping.

all the monkeys and apes and many other animals sit, and it is only this particular kind of sitting which correlates with the specialized anatomy.

#### DISCUSSION

Obviously, the theory that ischial callosities are sleeping adaptations amounts to little more than a guess when the evidence is critically examined. There is no survey of the sleeping habits of wild primates, and this guess is presented with the hope that others may be able to make some of the necessary observations. The use of infra-red equipment of the sort developed by the army during the war would make it possible to observe the monkeys at night without disturbing them. Quite aside from the particular point raised in this paper, data on all night behavior, about which nothing is known at the present time, might be gathered in this way. What is known now is that baboons often nap in a sitting position, that they may sleep that way at night, and that many Old World monkeys sit in a peculiar way. Admitting that many more data are needed and that the present explanation may have to be abandoned if it proves not to fit additional information, the remainder of this discussion will explore the implications of this explanation of ischial callosities *as if* it were correct.

Arboreal life affords monkeys a measure of protection during the night. The vast majority of enemies are ground-living, and even those which can climb into a tree must approach along narrow, limited routes. In the case of the baboons, the large males sleep on the larger, lower branches, and it appears that even a leopard will not climb up into a baboon sleeping tree. The same sleeping trees may be used for years, and their location must be known to the local carnivores. The ground below is covered with droppings and the tops of the branches are worn smooth by the baboons. But an attacking animal would have to fight several large males at the same time it was climbing. In the Wankie Game Reserve, Southern Rhodesia, I saw three cheetahs approaching

a mixed group of impala and baboons. I would have expected the baboons to retreat, but in fact one of the big males defied the cheetahs, roared at them, and the cheetahs trotted off in another direction. The impala clearly expected to be protected by the baboons because they made no effort to run away from the cats. This shows that quite large carnivores are careful about attacking baboons on the ground, and it would be far more difficult to attack in the large trees selected for sleeping. Granted the advantage of sleeping in trees, it is clear that a branch affords a wide platform for a little lemur, a narrow base to an average monkey, and a perilous perch to a great ape. Sleeping-sitting is *one* way of adapting to the advantages and problems of arboreal life. That it is not the only way is shown by the New World monkeys. If this theory is correct, they must have different sleeping habits from their distant cousins in the Old World.

Callosities are present in some 36% of chimpanzees (Schultz, '36 and '40) and occasionally in the gorilla and orangutan (Schultz, '41 and Miller, '45). *If* the sleeping-sitting theory is correct and *if* the apes have evolved from a quadrupedal monkey-like ancestor with ischial callosities, the great apes should differ from the monkeys in their sleeping habits. Gorillas (Bingham, '32), chimpanzees (Nissen, '31), and orangutans (Carpenter, '38, and '40, p. 41), all build nests, and, presumably, sleep lying just as they do in captivity. The great apes often sit, but they do not sit in the special Old World monkey way as described in this paper. When present, the callosities of the great apes are less well-developed than those of the monkeys, and they develop later (Miller, '45). Miller pointed out that the callosities of the apes might be regarded as either in the process of disappearance, or as a parallel development to those of the Old World monkeys. But parallelism occurs when similar genetic stocks are subject to similar selective pressures, and, if the sleeping-sitting theory is correct, the apes are not subject to the same pressures. They have grown too large to sleep in the monkey position, have learned to build nests, and the



callosities must be interpreted as in the process of disappearing. Parallel loss is occurring in the different great apes, as there is no longer selection to maintain the callosities, and the common ancestor of chimpanzee and gorilla and orangutan probably had them. Since well-developed callosities are correlated with a widening and characteristic shape of the posterior ends of the ischia, this guess may be proved, or disproved, when the necessary fossils are found.

Callosities are never found in man, and, since they are specialized structures, it has been suggested that they were never present in the ancestors of man (Miller, '45; Jones, '48, and Straus, '49). Wood Jones names the callosities as one of the principal reasons why man *could not* have been descended from either an ape or a monkey (Jones, '48, pp. 23 and 29). However, Schultz ('36) believed that man had lost callosities, at the time of the pelvic and muscular changes which made upright, bipedal locomotion possible. The evidence presented in this paper supports Schultz and the belief that man's ancestors had callosities. Actually, there is no biological reason why specialized structures should not evolve concomitantly with specialized habits and later be lost when the habits change. The belief that specialized structures cannot be present in ancestors is a relic of the formerly widespread belief in orthogenesis. Viewed from the standpoint of natural selection, it is no more improbable that our ancestors had callosities than that they sat and slept like monkeys and gibbons. The meaning of the structures lies in the associated habits, and the interpretation of evolutionary change requires the evaluation of structural complexes in terms of associated behavior. Anatomy alone offers no way to decide whether the callosities of chimpanzees are in the process of disappearing or appearing, no way to decide what the ancestors of man may have been like. Progress will come from field studies and experiments showing us the detailed function of the callosities and from the discovery of fossils in which the ischia are preserved.



## SUMMARY

The ischial callosities of the Old World monkeys are adaptations which make it possible for monkeys to sleep in a sitting position. This sleeping-sitting habit was observed in wild baboons, and the specialized kind of sitting (with feet up, hands near feet and most of the weight on the callosities) was seen in numerous Old World monkeys in zoos. The callosities of the apes are interpreted as in the process of disappearing, and it is probable that the ancestors of man had callosities.

## LITERATURE CITED

- BINGHAM, H. C. 1932 Gorillas in a native habitat. Carnegie Inst. Wash. publ., no. 426, p. 66.
- CARPENTER, C. R. 1938 A survey of wild life conditions in Atjeh, North Sumatra with special reference to the orang-utan. Communication no. 12 of the Netherlands Committee for International Nature protection, pp. 1-34.
- 1940 A field study in Siam of the behavior and social relations of the gibbon (*Hylobates Lar.*) *Comp. Psychol. Monog.*, v. 16: no. 5, pp. 1-212.
- CLARK, W. E. LE GROS 1934 Early forerunners of man. William Wood and Co., Baltimore.
- HOOTON, E. A. 1931 Up from the ape. Macmillan Co., New York.
- JONES, F. WOOD 1929 Man's place among the mammals. Longmans, Green & Co., New York.
- 1948 Hallmarks of mankind. Williams and Wilkins Co., Baltimore.
- MILLER, R. A. 1945 The ischial callosities of primates. *Am. J. Anat.*, 76: 67-91.
- NISSEN, H. W. 1931 A field study of the chimpanzee. *Comp. Psychol. Monog.*, v. 8, no. 1, pp. 122.
- POCOCK, R. I. 1920 On the external characters of the South American monkeys. *Proc. Zool. Soc. London*, 1: 91-113.
- 1925 The external characters of the catarrhine monkeys and apes. *Proc. Zool. Soc. London*, 2: 1479-1579.
- SCHULTZ, A. H. 1936 Characters common to higher primates and characters specific for man. *Quart. Rev. Biol.*, 11: 259-283.
- 1940 Growth and development of the chimpanzee. *Cont. to Embryol.*, 170, Carnegie Inst. Wash. Pub. 518, pp. 1-63.
- 1941 Growth and development of the orang-utan. *Cont. to Embryol.*, 182, Carnegie Inst. Wash. Pub. 525, pp. 57-110.
- STRAUS, W. L. 1949 The riddle of man's ancestry. *Quart. Rev. Biol.*, 24: 200-223.

# THE HARPENDEN ANTHROPOMETER

## A COUNTER-TYPE ANTHROPOMETRIC CALIPER

J. M. TANNER AND R. H. WHITEHOUSE

*Child Study Centre, University of London Institute of Child Health,  
Great Ormond Street, London; and Harpenden Growth Study*

ONE FIGURE

In any anthropometric work a number of obvious errors appear on scrutinizing the records when the survey or the measuring session is over (see Healy, '52; Tanner, Healy, Lockhart, McKenzie and Whitehouse, '56). One of the sources of such errors is misreading the measuring instrument, and since this is a problem common to many branches of science and industry, industrial psychologists have recently carried out experiments to find out what type of instrument panel or "display" is read most accurately. It seems, from the work of Gibbs ('55) and others, that many fewer errors are made in reading numerals which appear in a fixed window than in reading other systems such as pointers moving over a circular or semi-circular dial, cross-lines moving along a horizontal scale and so forth. The use of counter-type instruments might also be a first step towards making automatic recording instruments which would electronically punch the reading on a card, for use in very extensive surveys.

We have, therefore, designed a new and versatile anthropometer in which the reading is displayed on a counter. The Harpenden anthropometer is suitable for measuring all head, face and body diameters lying within the range 2 cm to 47 cm, and, with a bar attachment fitted to it, sitting and standing heights.

This caliper, the prototype of which is illustrated in figure 1. has two other advantages besides the counter-type read-

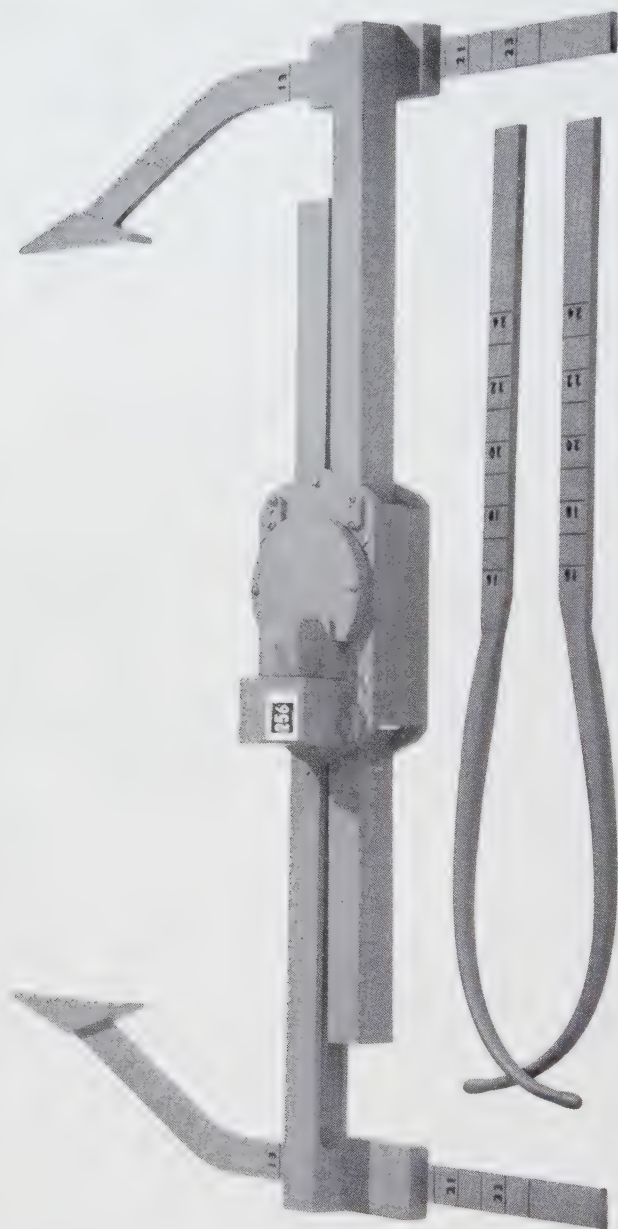


Fig. 1 Counter-type anthropometric caliper.

ing. By incorporating a rack and pinion to activate the counter we have achieved a smoother travel than can be obtained with the usual instrument; the new caliper can be opened and closed, if desired, by the fingers pressing on the tips of the extended arms, without any sticking or bending. Secondly, by designing the rack so that the two arms both move away from the centre of the instrument we have kept the counter central at all openings and enabled the caliper, when fully closed, to be only half the length of the conventional ones. The caliper, by having a portion of the sliding arms angled inwards while keeping the last 6 cm parallel, reads from 20 mm to 470 mm and when closed is only 34 cm, or about  $13\frac{1}{2}$  in. long. It is made of a light alloy, weighs  $1\frac{1}{2}$  lbs with the arms included and is balanced about its centre. It can be conveniently carried in a case  $35 \times 9\frac{1}{2} \times 7$  cm. The arms slide in and out as in the usual anthropometric caliper; two pairs are provided, the second one recurved and olive-tipped suitable for antero-posterior chest measurements, etc. The counter window is angled towards the operator so that it is in a plane perpendicular to the line of vision in the usual measuring position of operator and subject (the photograph was taken with the instrument placed in this measuring position, not flat; hence the apparent distortion of the side-arms).

For measurements of sitting height the caliper is attached to the top of a two-section bar, either 48 cm or 58 cm long, according to whether children or adults are being examined. For standing height a similar arrangement is used.

The new caliper is made by A. E. Mash and Associates, 25 Shaftesbury Avenue, London, W. 1., and costs approximately £40, the two pairs of arms and the case included.

#### ACKNOWLEDGMENTS

We wish to thank Professor J. V. Connolly for his help in making the first prototype; and the Medical Research Council for financial assistance.

## LITERATURE CITED

- GIBBS, C. B. 1955 Psychological aspects of machine design. Machinery, May 6, 8pp.
- HEALY, M. J. R. 1952 Some statistical aspects of anthropometry. J. Roy. stat. Soc. B., 14: 164-184.
- TANNER, J. M., M. J. R. HEALY, R. D. LOCKHART, J. D. MCKENZIE AND R. H. WHITEHOUSE 1956 Aberdeen Growth Study I. The prediction of adult body measurements from measurements taken each year from birth to five years. Arch. Dis. Childh., 31: 372-381.



## THE KWANGSI JAW

JOHN HILLABY

*European Science Correspondent, London Bureau, New York Times*

ONE FIGURE

Speculation about the phylogeny of the primate described as *Gigantopithecus blacki* by von Koenigswald ('35) has been published in great detail by Weidenreich ('45). If the lower jaw of a large Pleistocene ape which was discovered recently in Kwangsi Province, South China is, indeed, that of *Gigantopithecus* then Weidenreich's principle assumption that the primate had hominid rather than pongid affinities is wrong. The jaw, nevertheless, would seem to be of interest for many other reasons. Unfortunately, as far as I know, it has not yet been described. As I am indebted to Dr. Pei Wen-chung of the Academia Sinica in Peking for a photograph and some facts about the specimen, it may be of value to place on record my sources of information for an account of the discovery which appeared in an abbreviated form under my name in the *New York Times* of the 17th of March, 1957.

In a magazine article, Pei ('56) reported that the Academy of Sciences in Peking had received many paleontological specimens as a result of an extensive campaign to educate peasants throughout China on the historical value of fossil remains. In the hope that the "Karst" limestone hills of Kwangsi would yield remains of *Gigantopithecus*, Dr. Pei says he directed the activities of a work team in Nanning where several thousand pounds of bones had been purchased from local residents.

In the magazine article Pei wrote: "Besides great numbers of fossil bones of the giant panda (*Ailuropoda*), the elephant-like *Stegodon*, rhinoceros, the big tapir (*Megatapirus*), boar

and deer, we discovered 7 teeth of *Gigantopithecus*, all of them three times the size of human teeth, and larger than those described by von Koenigswald. We also picked out about 700 teeth of orang utan (*Pongo pygmaeus*) and scores of smaller teeth of an ape-like man. We later identified 30 more *Gigantopithecus* teeth among fossils collected in Canton. Between January and March our work team, basing itself on information from local residents, carried out preliminary investigations in about three hundred caves in Laipin, Shanglin, Liuchiang, Wuning, Tahsin, Fusui and Chungtso counties, all in western and central Kwangsi."

"In a cave in Tahsin county we located three more *Gigantopithecus* teeth. This was our first view of such relics in the locality, cave and stratum in which they were found. These teeth were in a layer of red loam beneath a layer of hard breccia where fossils of the giant panda, orang-utan and other mammals often found in caves south of the Yangste had accumulated. The fossiliferous hard breccia is from the Middle Pleistocene geological age . . ."

I wrote to Dr. Pei and asked him for further information. Some days later I heard, independently, from the New China News Agency in London that a jaw said to be that of *Gigantopithecus* had been found in Kwangsi. The agency daily bulletin (No. 1753) read as follows:

"Peking, February 17. New discoveries about the giant ape, *Gigantopithecus* tend to show that this anthropoid was closer to man than any other ape yet discovered, though not as advanced as an apeman. Paleontologist Dr. Pei Wen-chung who announced this today at the opening session of the annual meeting of the Paleontological Society of China has recently returned from Kwangsi where he has been directing the cave excavation work. He displayed a fossil lower jaw bone of the giant ape with twelve teeth in place which had been found by a peasant and since subjected to careful examination. Together with the fifty teeth previously examined, it showed that the ape probably had a mixed vegetarian and meat diet, Dr. Pei said. They indicated that the

giant ape was already emerging from apehood, approaching the status of man but was not so advanced that it could be placed in the human family. It had conceivably developed only in size, he added, but not the corresponding ability to hunt animals, in other words the capacity for labor."



Figure 1

"No weapons or tools had been found in the limestone caves in which the ape had lived, Dr. Pei said. The caves were up a steep cliff 90 m high and contained bone fragments of boars, deer and other animals, presumed to be the remains of the ape's food. Examination showed these remains to be of either very young or very old animals, leading to the view

that they could have been caught without weapons. Dr. Pei pointed out that the jaw bone was roughly twice the size of a present day human jaw and was a smaller type of giant ape jaw. Its size and the much-worn teeth indicated an old female ape."

"The jaw has six teeth on the left side from the lateral incisor to the second molar and six teeth on the right, from the medial incisor to the second molar with a lateral incisor missing. Dr. Pei explained that the teeth were arranged not in two parallel lines as is common in an ordinary ape's jaw. The shape and position of the canine was neither conical nor raised above the other teeth. These were characteristics of the human group, he said. However, the outward curve was still narrower than that of the apeman. In addition, the lower jaw had a simian shelf . . . yet not so marked as that of ordinary apes . . . Among the avenues that had to be explored were also the reasons why it attained such an enormous size—estimated at between  $3\frac{1}{2}$  to 4 m tall, and how it achieved a mixed diet . . ."

In a letter dated the 2nd of March, 1957 I received three copies of a photograph of the jaw from Dr. Pei. He said that his "first opinion" was that: (i) the jaw was a specimen of *Gigantopithecus* and could be related to the Middle Pleistocene; (ii) that this was "fundamentally a giant ape" and that he, Dr. Pei, endorsed "von Koenigswald's first idea;" (iii) that the jaw showed "more human characteristics than any other known fossil or recent ape;" (iv) that it was contemporary with *Sinanthropus* and (v) that it had "more anthropoid characters as shown by the larger incisors and canines and the curvature of the mandibular arch" than *Paranthropus*. The jaw is believed to have been located at Liuchiang by a peasant, Tan Hsiu-Luai who was digging for phosphate fertiliser.

The original copies of the photograph of the jaw have been sent to the British Museum (Natural History) and, at Dr. Pei's request, to Dr. von Koenigswald. After some initial doubts Dr. von Koenigswald seems to be convinced that the

specimen depicted is indeed that of *Gigantopithecus* "probably a female" he says. In a private communication he adds that the teeth resemble isolated specimens which he has collected from Chinese drugstores but which have not yet been described.

According to the news agency report, Dr. Pei considers that the Kwangsi jaw is a relic of a "smaller type of giant ape" but he is reported as saying that its height has been "estimated at between  $3\frac{1}{2}$  to 4 meters." Estimates of this kind are unfavorably regarded here. It has been pointed out that in *Paranthropus* which, in this instance may be compared with *Meganthropus* of Java, the mandible is relatively enormous, in some specimens larger even than the Kwangsi jaw; nevertheless, the pelvis of *Paranthropus* suggests a being of moderate height.

## LITERATURE CITED

- VON KOENIGSWALD, G. H. R. 1935 Eine fossile Säugetierfauna mit *Simia* aus Südchina. Proc. Kon. Akad. Wetenschappen. Amsterdam. Tome 38 (8): 872-879.
- PEI, W. C. 1956 "New Material on Man's Origins." China Reconstructs. London. Vol. V, No. 8: 9-11.
- WEIDENREICH, FRANZ 1945 Giant Early Man from Java and South China. Anth. Papers. Amer. Mus. Nat. Hist., Vol. 40, Pt. 1: 1-134.







## VIKING FUND MEDALIST FOR 1956

The Viking Fund Medals and Awards for 1956, given by the Wenner-Gren Foundation for Anthropological Research, were presented following a dinner at the Plaza Hotel, New York, on March 1, 1957. Doctor Wilton M. Krogman was toastmaster. Doctor Paul Fejos represented the Foundation in the absence of Doctor Wenner-Gren, who was in Mexico. Doctor Charles W. Goff, Chairman of the Association's Awards Committee, read the following statement in presenting Doctor Trotter for the high honor — incidentally the first woman to be so honored:

“The Awards Committee of the American Association of Physical Anthropologists has always been composed of men. The majority of the Association's members are men and all past medalists have been men. This year the Committee broke the tradition by recommending a lady, Dr. Mildred Trotter, Professor of Gross Anatomy, Washington University, St. Louis. She was selected for the 1956 Viking Medal and Award, not because of any single discovery, but because of her high attainments in fields identified with our interests; her consistently good quality of work, her capacity for hard work, and her administrative achievements. These have made her unique in the field of physical anthropology.

“I can, but I will not, tell you when she was born. A relatively few years ago this event took place in Monaca, Pennsylvania. She received the A.B. degree from Mount Holyoke College in 1920; the Master's in 1921 and the Ph.D. in 1924 from Washington University under Professor R. J. Terry. During one summer of this period she studied invertebrate zoology at the Woods Hole Marine Biological Laboratory, and during another, human embryology at the University of Wis-



MILDRED TROTTER

consin. As a National Research Council Fellow, she spent the year, 1925–26, working with Professor Arthur Thomson in the Department of Human Anatomy, Oxford University, England. Later in the twenties, she studied radiology at Washington University, pathology at the University of Michigan, and more anatomy at Stanford University.

“She traveled extensively in the United States, Canada, British Isles and on the Continent, visiting laboratories and scientific museums, especially the Anatomical Laboratories at the University of Berlin; the Anthropological Institute, Rome, and the Museum of the Royal College of Surgeons, London. These many contacts prepared Doctor Trotter unusually well for her post at Washington University.

“At the University Doctor Trotter has risen in her chosen field of anatomy and physical anthropology, step by step, from research associate in 1920, to assistant in 1922, and on through the ranks to professor of gross anatomy in 1946. She served as special Consultant to the U. S. Public Health Service from 1943 to 1945; as Anthropologist to the U. S. Department of Army at Schofield Barracks, Hawaii, in 1948–49 and at Fort McKinley, Philippine Islands in 1951; and, has been Consultant in anatomy to the Mallinckrodt Institute of Radiology since 1948.

“In searching for material to serve me in my introduction, I received many fine tributes to ‘Mildred.’ One eminent physical anthropologist put things this way: ‘Mildred has been consistently sound. Her research work on skin and hair will survive a long time, and now her recent work on stature and weight has added both to each.’

“Doctor Trotter has succeeded in fields usually dominated by men. Her achievements, while serving with the Graves Registration Service in Hawaii and Manila after World War II, are especially remarkable. The embalmers and the GI’s in the Identification Laboratory expected her to give up the first day. As Dale Stewart has expressed it, ‘She knew, of course, what she was getting into and could take it in her stride.’ She confided in him, however, that the work was so tiring that for

the first few weeks she was not sure she would last out each day. Yet, not only did she do so, but she talked the brass into letting her do research and, as a result, we are indebted to her for the best stature reconstruction formulae.

“One of the things that impresses every one is her capacity to remain so feminine in spite of the tough type of work in which she has been engaged. That may account, in part, for her successes. At any rate, she is very feminine, a trait that everyone, even the anthropologist, appreciates.

“Mildred has already been honored in various ways for her accomplishments. The following are especially noteworthy: An honorary Doctor of Science degree from Western College for Women; trusteeship at Mount Holyoke College; membership in the Anatomical Society of Great Britain and Ireland; appointment on the Missouri State Anatomical Board; presidency of the Anatomical Board of St. Louis; and last but not least she is now the President of the American Association of Physical Anthropologists, and by rights of that office, should be introducing herself.

“Her list of publications fills four closely typed pages which I shall not read. Bibliographies are usually reserved for obituaries, and Professor Trotter is very much alive. She is best known for her work on age changes in head hair from birth to maturity and for her recent analyses of skeleton weight and stature. In this connection she has put to good use the Terry skeleton collection and has served as its custodian most effectively. Also, we are indebted to her for many interesting and useful papers on skeletal anomalies, etc.

“With such a command of anatomical subjects, Doctor Trotter is, of course, an extraordinarily fine teacher in this field. That she is equally at home in the field of physical anthropology is shown by her address on ‘The history of the American Association of Physical Anthropologists,’ which she gave to the Association at its annual meeting in April, 1956. Future investigators who are concerned with the beginnings of the American Association of Physical Anthropologists will do well to read her story.



“It is with honor and pleasure, therefore, that I present Dr. Mildred Trotter, in recognition of her success in combining the fields of anatomy and physical anthropology and especially her contributions to the study of human hair and problems of identification.”



## REVIEWS

PRIMATOLOGIA: HANDBOOK OF PRIMATOLOGY. Part I. Systematics, Phylogeny and Ontogeny. Edited by H. Hofer, A. H. Schultz, and D. Stark, pp. XXII + 1059. S Karger, Basel. 1955.

This is the first of a 5 volume Handbook whose stated purpose is “. . . to assemble and augment all relevant knowledge, to clarify old as well as new problems, and to stimulate and intensify the investigation of primate morphology.” Such a purpose is not only laudable but also deserving of considerable encouragement in its own right. There is certainly a new day dawning in the world of primatology; a day which will see an increased use made of primates in the various fields of experimental biology and psychology. To predict the course of events for the future would be presumptuous but probably Yerkes was correct when he said that the emphasis should be on the problem rather than on the primate. Certainly we are in need of reviews or handbooks which will give to the newer investigators an up-to-date picture of the current status of primatology. Apparently it is the purpose of this Handbook, in its entire 5 volumes, to present this type of picture.

The editors have chosen primate phylogeny and ontogeny as their organizing theme with “. . . the problem of man's place among the primates . . .” forming “. . . the leading motif.” The material is to be organized by anatomical systems instead of by taxonomy. “Thereby this handbook may be less ‘handy’ for taxonomists, but more advantageous for comparative anatomists and for the steadily growing group of scientists who use non-human primates for medical, physiological and other investigations. It is to be expected that such a systematic presentation of primate anatomy, in spite of all the still existing gaps, is bound to reveal the position of man among the primates more clearly and in a more fully supported manner than heretofore.” Whether these objectives can be achieved cannot adequately be judged from a single volume. This first volume is really an introduction for an extended work, but it should give some idea of how the editors intend to implement their statement of purpose.

Proposed titles of subsequent volumes are:

Vol. II. (1) Skin and Sense Organs; (2) Nervous System.

Vol. III. Circulatory System, Blood, Digestive System, Urogenital System, Body Cavity and Situs, and Endocrine Organs.

Vol. IV. Musculo-Skeletal System.

This first volume on systematics, phylogeny and ontogeny includes 9 papers as follows: (1) Fiedler, W. — Review of Primate Taxonomy (267 pages); (2) Remane, A. — Paleontology and Evolution of the Primates Especially the Non-Hominoidea (111 pages); (3) Heberer, G. — Paleontology of the Hominoidea (183 pages); (4) Harms, J. W. — Biology of Reproduction (161 pages); (5) Harms, J. W. — Pregnancy and Birth (62 pages); (6) Starek, D. — Early Development and Placentation of Primates (164 pages); (7) Schultz, A. H. — Postembryonic Age Changes (78 pages); (8) Schultz, A. H. — The Occurrence and Frequency of Pathological and Teratological Conditions of Twinning among Non-Human Primates (50 pages); (9) Kramp, P. — Serological Phylogenetic Investigations (20 pages). The two papers by Schultz are the only ones in English; all others are in German.

The paper by Fiedler is a classification of the primates which neither he nor the editors feel can be the last word on this perplexing subject. It is to be used by the other contributors to eliminate confusion due to differences in terminology. Fiedler chooses to include the Tupaiiformes as a superfamily of the Prosimiae as contrasted with Hill (see Straus' review of Hill, AJPA, '56). Fiedler recognizes the difficulties of defining the primates under these circumstances but would agree with Straus that regardless of how they are classified the Tupaiiformes must be considered in primate evolution.

A comparison of Fiedler's classification with those of Hill ('53 and '55) and Simpson ('45) shows differences which are on the whole minor. The paper is well illustrated both with pictures of representative forms and with distribution maps. This will be a very useful paper.

The two papers on paleontology should be of interest to students of primate evolution; they were a disappointment to the reviewer. There is a notable lack of any attempt to make use of recent concepts in the field of evolution. Simpson is referred to at length but apparently no use has been made of his tempos and modes. Patterson (Hum. Biol., '54) is referred to by both authors yet neither has heeded his criticism of genealogical trees. The reader is left with the idea that there are a tremendous number of Primate fossils, but this idea is only possible because of the lack of emphasis on the time and geography over which these fossils are distributed. As an interpretive paper Patterson's 18 pages are in some respects better than

these 294. As annotated bibliographies these are good and will be of use to those wishing ready reference to the original papers.

Turning to the ontogeny papers, Harms gives a very good review of sex differences both in soft parts and in size during growth for those forms which have been sufficiently studied (primarily Macaque and Chimpanzee). There is a good discussion of the literature dealing with the various aspects of the menstrual cycle and birth. The important contribution is the inclusion of some excellent, unpublished data on the Java Macaque collected by Spiegel.

Starck presents a review of current knowledge of spermatogenesis, placentation, and especially embryology. Considering the contributions which studies of Macaque embryology have made to our present ideas of human embryology, this paper is particularly valuable.

Schultz's first paper is a very good review of his earlier works. His Introduction and section on "Growth in Absolute Size, Life Periods and Rates of Growth" are especially good and should be read by everyone working with primates. Unfortunately these sections encompass only 10 of the 78 pages in his first paper. The next 40 pages deal with age changes in proportion. This is not the place to air the reviewer's personal prejudices concerning indices; suffice it to say that the known age changes in indices are contained in these pages. The final section on "Developmental Age Changes" is a good summary of present knowledge in the field.

The review of pathology brings together Schultz's earlier work in this field as well as that of other investigators. The primary interest is on the skeleton with nothing about infectious diseases which are of such interest to those who anticipate using primates in the laboratory.

The more than one thousand pages in the present volume are but the beginning of an extended work on the primates. There can be no question but what these animals will play an increasingly important role in the research of tomorrow, and it is the editor's and the reviewer's hope that these volumes will aid in making that research more valuable. These expectations will undoubtedly be fulfilled with respect to investigations centered around the problem of phylogeny and ontogeny. However, it is the reviewer's opinion that those "... scientists who use non-human primates for medical, physiological and other investigations" will find the organization used by Hill of more value. This is not said in the sense of criticism, but rather to indicate that these volumes will be of interest to a particular audience — those interested in Primate evolution — instead of to experimentalists generally.

The editors' statement of purpose definitely looks to the future, but the reviewer got the impression that this volume primarily at-



tempts to arrange and classify. There is little attempt either to use the material to test newer concepts of evolution or to question the utility of methods in terms of more recent data. While this is an excellent summary of accomplishments to date, it does not point directly to the problems of tomorrow.

The papers are well illustrated; the volume is well indexed; some of the paper is of good quality, but it is not well bound.

JAMES A. GAVAN

*Medical College of South Carolina*

---

BONES FOR THE ARCHAEOLOGIST. By I. W. Cornwall, pp. 255. \$7.50. Macmillan, New York. 1956.

A background in comparative osteology is essential for workers in archaeology and of considerable value to physical anthropologists since most historical studies of ecology and evolution are based in large part on bone material. I. W. Cornwall's *Bones* appears to be a source from which much of this background can be gleaned and we are most fortunate in being provided with this excellent guide to knowledge in a related discipline.

The author has attempted to assemble sufficient data on the comparative osteology of the *Mammalia* to enable the student of archaeology to sort and roughly classify bone material brought to light in excavation. He confines himself to the characteristics of mammalian orders likely to be found by the British archaeologist, for whom the book is designed. Despite this geographical limitation the work is an excellent text in comparative mammalian osteology, especially valuable since no similar work has been in print for many years (since Flower's *Osteology of the Mammalia*, 1885). The book is not purported to be an atlas for specific identification, but is meant as a general guide to be used with comparative collections of osteological material in taxonomic studies. As such, the confinement of illustrative material to Old World species does not materially handicap the American student, although a comparable work using New World material would certainly be most welcome.

Introductory chapters cover the purpose of the book and a brief outline of organic evolution. While the latter adds depth to the following technical material, several of the views expressed (e.g. man's future adaptation as social rather than biological) might be questioned by many students of evolution.

Cornwall follows Flower's presentation closely, dealing in the main body of the book with the major divisions of the skeleton as seen

in each taxonomic order. An emphasis on human osteology, prolific illustrations, and numerous examples of adaptational changes in bone structure through evolution add to the value of the book as a reference in physical anthropology. A chapter dealing with the aging and sexing of skeletal material is largely confined to the interpretation of human remains and, while admitting that statistical population studies are the surest key to the determination of sex in skeletal material, Cornwall restricts himself to the standard qualitative observations (pelvic girdle shape, pre-auricular sulcus, etc.). Further interpretation is left to the specialist in physical anthropology. The reader is frequently reminded of the context in which the archaeologist is working; and a separate chapter is devoted to the limitations and possibilities in the archaeological interpretation of skeletal remains.

Considerable useful anatomical terminology is presented in the course of the text, and it is here that the lack of an index will be most sorely felt by readers unfamiliar with the material. The inclusion of this feature should be considered essential in any future revision. In addition, a few minor errors might be mentioned. One view of the human humerus (fig. 39a) is illustrated with a pronounced proximal extension of the greater tuberosity, far more than is normal in man. The vertebral formulae (pp. 112-113) vary to some extent from those given by Flower; the *Rodentia* especially seem oversimplified, even in the limited context of European families. On page 150, under *Proboscidea*, line 3, "tarsus" should obviously read "carpus."

The above-mentioned limitations do not greatly modify the value of the book as a reference and basic text in comparative mammalian osteology for interested anthropologists. It is to be hoped that with this reference available, osteological material recovered by archaeologists will be put to much fuller use in interpretation than has been the case in the past.

ARTHUR J. JELINEK  
*University of Michigan*

---

THE AETIOLOGY OF IRREGULARITY AND MALOCCLUSION OF THE TEETH. 2nd ed., part 1, by James Couper Brash. Part 2 by H. T. A. McKeag and James H. Scott, with an appendix by Miriam L. Tildesley. xiv + 503 pp. \$6.00. Dental Board of the United Kingdom, London. 1956.

This long and comprehensive work constitutes at once a new edition of the book published by Doctor Brash in 1929, and an addendum by Doctors McKeag and Scott covering the literature since that time.

The first part, which is the original Brash, is interesting to reread. As long as it comprises an assemblage of pictures and descriptions of tooth alignment in sundry and odd conditions, and numerous developmental defects, it is not satisfying by contemporary standards. But when it turns to experimental studies on cranio-facial growth, the older work has real freshness despite its years. Incidentally Walkhoff's ('10) experimental modification of facial form by unilateral muscle resection is pictured on page 223.

In the second part of the book, McKeag and Scott have critically reviewed and cited selections from the literature since 1929—a Herculean task at the very least. Under these circumstances, the text occasionally becomes a recital of who-did-what, or brief quotations from each of many authors. However, the net quality of the addition is high, and the authors are by no means reluctant to admit deficiencies in the articles quoted. Readers familiar with the literature will certainly agree with McKeag's comment that while scientific and speculative papers are both desirable, many authors cannot make up their mind which they are writing!

In an appendicular chapter, Miss M. C. Tildesley goes into the question of "rightness" (i.e. normality), measurement, standards and statistics. While primarily a dissertation on the normal curve, with references to problems involving the product-moment correlation, the following gem breaks through to light . . . "ailing mothers tend to produce ailing children, ailing children tend to wail, and wailing children are more likely to have their mouths stopped with a dummy."

The General Dental Council of the United Kingdom in printing a new and revised edition of "The Aetiology of Irregularity and Malocclusion of the Teeth" has produced quite a bargain. For two guineas, \$6.00, at the present rate of exchange, one gets 503 pages, 224 illustrations, 81 tables, and 37 pages containing approximately 1600 references.

STANLEY M. GARN  
*Fels Research Institute*  
*Antioch College*

GIFT TO THE UNIVERSITY OF PITTSBURGH  
by JOHN GILLIN

## SKELETAL PATHOLOGY OF EARLY INDIANS IN TEXAS<sup>1</sup>

MARCUS S. GOLDSTEIN

*Division of Public Health Methods, U. S. Public Health Service, Washington, D. C.*

TWO FIGURES

Health status of a group, as pointed out by Sigerist ('43), Angel ('47), Krogman ('40), and no doubt by others, may have a profound influence on the cultural attainments and very survival of the group. For early preliterate groups of man the main or perhaps only index of health status is that revealed by their skeletal remains: the pathological-teratological defects manifest in the bone, and the approximate age at death, the "life-span," as determined on the skeleton.

Data are here presented on frequency and types of obvious abnormalities in skeletal remains of Indians examined by the writer at the University of Texas (Goldstein, '48). The skeletal material came from all the major regions of the state, although most of it was from south, central, and northeast Texas. The remains represent peoples living about 800-1700 A. D. (Krieger, '46). Average life-span of these same Indians has been estimated to have been about 30 years (Goldstein, '53). Dental pathology in these Texas Indian remains has also been considered previously (Goldstein, '48), and is not included in the present count of defects.

### *Prevalence of affected crania and skeletons*

Crania and skeletons are considered separately since, in many instances, only the skull was recovered, or bones were found in a group burial and skulls and skeletons could not be related with certainty.

<sup>1</sup> I am grateful to Dr. T. Dale Stewart for a critical perusal of the paper and helpful suggestions.

As noted in table 1, some abnormality occurred in about 30 percent of the adult crania and 40 percent of the skeletons. Only fairly complete skeletons were included in the latter group, except some very incomplete skeletons which showed definite pathological lesions. The proportion of skulls and skeletons with pathological or teratological defects, as might be expected, in each instance tends to be higher in old age than at any other period.

TABLE 1

*Skeletal remains of early Indian groups in Texas, by sex and age, manifesting pathological lesions and/or abnormalities*

SEX AND AGE	CRANIA			SKELETONS (EXCLUDING CRANIA)		
	Total number	Affected		Total number	Affected	
		Number	Percent		Number	Percent
Adults:						
Both sexes <sup>2</sup> .....	348	106	30.5	146	58	39.7
Male .....	179	58	32.4	89	30	33.7
Female .....	157	40	25.5	57	28	49.1
Approximate age: <sup>1</sup>						
(both sexes)						
Juvenile .....	73	13	17.8	33	2	6.1
18-30 .....	130	28	21.5	31	9	29.0
35-50 .....	137	42	30.7	40	13	32.5
55+ .....	81	36	44.4	21	12	57.1

<sup>1</sup> Age could not be estimated with any degree of accuracy on many skeletons and thus differences occur between the total number of "adults" and the total numbers by age.

<sup>2</sup> Included in "Both sexes" are several cases of undetermined sex, and hence the numbers vary somewhat from the sum of the male and female crania.

### *Types of abnormalities*

The prevalence of different "kinds" of abnormalities observed in the crania, in relation to sex and broad age groups, is shown in table 2. Palatal abscess here refers to complete destruction of parts of the palatal floor, usually in the molar region, possibly the result of initial alveolar abscess.

Exostoses in the auditory meatus was the most common defect in the skull of these Indians. These growths apparently



occurred in the adult only, much more frequently in the male than among females, and in an increasing proportion of cases with an advance in age. Hrdlička ('35) in his large work on ear exostoses also noted the almost complete absence of the defect in childhood, as well as its much greater prevalence among males. However, in apparent contrast to the present results, he found the condition "dominantly one of earlier to middle adult life, [which] has very little if any connection

TABLE 2

*Types of pathology in crania of early Texas Indian groups, by sex and age*

DEFECT	ADULT			AGE (BOTH SEXES)			
	Both sexes <sup>1</sup>	Males	Females	Juvenile	18-30	35-50	55+
Total number . . .	348	179	157	73	130	137	81
Per cent of total number							
Auditory exostoses . . .	10.3	17.9	1.9	..	5.4	9.5	19.8
Traumatic lesions . . .	10.1	7.9	9.5	..	8.5	10.3	12.3
Lesions in glenoid fossa (arthritic?) . . . . .	4.6	4.5	4.5	..	3.6	2.9	8.6
Osteoporosis . . . . .	4.6	3.9	5.7	15.1	4.6	4.4	4.9
Syphilis (?) . . . . .	1.4	0.6	1.9	..	0.8	1.5	2.5
Palatal abscess . . . . .	1.1	1.2	1.2	..	..	2.2	1.2
Exostoses, other than auditory . . . . .	0.6	0.6	0.6	..	..	1.5	..
Inflammatory lesions ..	0.3	..	0.6	2.7	..	0.7	..

<sup>1</sup> The number of crania under "Both sexes" includes cases of undetermined sex.

with senility and its disorders" (p. 25). Hrdlička, discussing etiology in his monograph, favored hereditary predisposition as the primary factor in the occurrence of ear exostoses, and cited much evidence from the literature in support of this hypothesis. He also mentions fronto-occipital cranial deformation as a possible contributing factor in its appearance. Only the crania from East Texas manifested deformation of the fronto-occipital kind; and only a comparatively small number from this area showed ear exostoses (7 of 39 male crania, compared with 11 of 26 undeformed male skulls from North Texas).

Traumatic lesions, apparently the result of blows or cuts, occurred in just about as many crania as did ear exostoses. It may be noted that among the Pecos Pueblos (Hooton, '30), crania with fractures or "other traumatic lesions" totaled 8.8 percent, which is about the same proportion found in Texas (10.1 percent).

Five skulls had more or less the gnarled and pitted appearance suggestive of a history of syphilis. Three of these crania were from historic sites, two from pre-white contact sites.<sup>2</sup> Three of these skulls are illustrated in figure 1.

A word may be said about the question of the occurrence of syphilis in pre-Columbian America. Skeletal remains of Europeans dating back to a period before the advent of salvarsan or antibiotics might be examined for gross lesions due to syphilis. If syphilis, a highly infectious disease, left its mark on the bones of a relatively large number of its victims, then the claimed evidence for syphilis in the pre-Columbian Indian, based as it seems to be on a few specimens only (Stewart, '40, p. 31), would hardly be convincing; on the other hand, should only a few skeletons manifest clear marks of the disease, the evidence supporting its presence in the Americas before the time of Columbus, scant though it be, would necessarily bear much weight.

Table 3 shows the prevalence of skeletons with various types of pathological or developmental defects by broad age groups. Inflammatory lesions refer to a thickening or swelling of the bone. Sigerist ('51, p. 49) has remarked that "It is no exaggeration to say that the great majority of all pathological changes found in early human and animal bones are the result of inflammatory processes." This observation is borne out in the skeletal remains of the early Indians in Texas.

Tuberculosis and possibly syphilis may have been responsible for some of the lesions noted (figs. 1 and 2). The category

<sup>2</sup> The white-contact sites were the Womack Farm, Lamar County (Catalogue No. 417); Espiritu Santo Mission, Goliad County (Catalogue No. 315); Clements Farm, Cass County (Catalogue No. 426). The pre-white contact places were Sanders Farm, Lamar County (Catalogue No. 411); and Willison Farm, Bell County (Catalogue No. 660B).

of "Fracture" should probably be increased by about 5 percent at the expense of "Inflammatory lesions" since the hypertrophy in some cases was smooth and localized and may represent healed fractures.

TABLE 3

*Type of pathological changes and abnormalities in skeletons (excluding crania) of early Indian groups in Texas, by age*

DEFECT	ESTIMATED AGE (YEARS)				
	Total adult	18-30	35-50	55+	Juvenile
Total number .....	92	31	40	21	33
	Percent of total number				
Inflammatory lesions .....	28.3	25.8	30.0	28.6	3.0
Osteoporosis .....	3.3	3.2	..	9.5	..
Patellar abrasion (arthritic?) .....	2.2	..	..	9.5	..
Resorption of bone .....	1.1	..	..	4.8	..
Traumatic (?) knob .....	1.1	..	2.5	..	..
Fracture .....	1.1	..	..	4.8	..
Fused ribs .....	..	..	..	..	3.0

### *Single bones affected*

Of the listed bones in table 4, the tibia was by far the most frequently affected, usually by gross hypertrophy of the shaft. As already noted, inflammatory lesions of the smooth type, as well as perhaps the bones manifesting resorption, may be the end result of old fractures. The descriptive category "gnarled bumps" seems to correspond to Moodie's ('23, Plate 88) "hypertrophy due to osteomyelitis or syphilis (?)."

Observations on the fibula and ulna, not listed in the table, gave the following results: 19.6 percent of 168 fibulae and 11.3 percent of 229 ulnae manifested pathological changes, preponderantly a rough and generalized hypertrophy of the shaft.

A word may be said about the location of the inflammatory lesions on the long bones. Taking the tibia as an example, of 78 bones with pathology (inflammatory lesions), one-third were affected pretty much over the whole shaft; 30 percent

showed lesions on approximately the middle half of the shaft only, usually the internal aspect; 22 percent manifested "swelling" in the upper quarter of the shaft only; 14 percent showed hypertrophy on the lower quarter of the shaft only; one percent appears to be unaccounted for.

TABLE 4

*Frequency and kinds of defects in certain bones of the skeleton in the remains of early Indian groups in Texas*

DEFECT	BONE				
	Tibia	Femur	Radius	Humerus	Clavicle
Total number examined	310	362	194	295	174
	Percent affected				
Total	30.3	8.6	6.7	6.4	5.7
Inflammatory lesions	25.7	4.8	5.1	2.4	2.3
Rough	21.6	3.4	3.6	1.0	2.3
Smooth	4.1	1.4	1.5	1.4	..
Gnarled bumps (general)	..	0.3	..	..	..
Fungoid excrescence	2.9	0.8	..	0.3	..
Exostoses (mod. or pron.)	0.6	0.6	0.5	2.0	2.3
Lipping of condyles (mod. or pron.)	0.6	1.4	..	0.3	..
Fracture	0.3	0.3	..	..	..
Erosion	..	0.3	1.0	0.7	..
Resorption	..	0.3	..	..	1.1
Marked curvature	..	..	..	0.3	..
Aplasia	..	..	..	0.3	..

### *Regional variations*

To what extent did the frequency of gross skeletal abnormalities differ among the various groups unearthed? Regrettably, this question cannot be answered definitely since fairly complete skeletons by site or even by region are few in number. Thus, only 4 such skeletons from West Texas and 5 from North Texas could be examined for pathological changes. Somewhat better although still inadequate series were available for several archeological sites, and the relative numbers

of skeletons with abnormalities among these groups are listed below:

SITE AND REGION	SKELETONS EXAMINED	PERCENT WITH ABNORMALITIES
Oso (South Texas) .....	22	59.1
Caplen Mound (South Texas) .....	9	55.5
Sanders Site (East Texas) .....	26	53.8
Mitchell Farm (East Texas) .....	24	37.5
Morhiss Mound (South Texas) .....	13	30.8
Goliad Mission (South Texas) .....	9	11.1

All of the sites except the Goliad Mission were pre-Columbian in time; the Sanders and Mitchell sites in northeast Texas revealed the practice of agriculture; the Oso, Caplen Mound and Morhiss Mound groups, located near the Gulf, apparently did not practice agriculture.

### *Miscellany*

Few vertebral columns were complete or in a good state of preservation. Of 56 skeletons of adults, 35 or 62.5 percent manifested lipping in the lumbar vertebrae. Of 17 complete sacrums, 13 had 5 segments, one had 4 segments, two had 6 segments, and one had 7 segments (a coccygeal fused to the 6th).

### DISCUSSION AND SUMMARY

The preceding data referred primarily to the frequency of crania, skeletons, and single bones affected by pathology or developmental defects. What should perhaps also be noted is the fact that actually some 70 percent of the total adult crania and 60 percent of all the skeletons and by far most of the individual bones, showed no pathology or abnormality whatever, so far as could be discerned by the writer. To be sure, although every bone was carefully examined, some pathological or teratological condition may not have been recognized, since observations on pathology were incidental to a general metric and morphological study of the skeletal material and,



moreover, the writer had no special competency in the field of pathology. Even assuming a maximum of 10 percent of under-recording of skeletons with pathology, however, there would still remain half or more of the skeletons with no mark of disease or abnormality. Furthermore, some at least of the observed pathology could scarcely have been of a serious or long-disabling nature.

In regard to causes of, or diseases associated with, abnormalities observed in the bones, hypertrophy due to possible chronic infectious diseases such as syphilis and tuberculosis has been noted, as have degenerative conditions such as vertebral lip-ping, osteoarthritis (e.g., in glenoid fossa), and tumors. Hooton ('30, p. 308) felt that periostitis of the long bones might be due "to some non-specific infection such as streptococcus or staphylococcus, or possibly syphilis," while Sigerist ('51, p. 49) has observed that "Periostitis is often caused by an injury such as a 'blow'."

To recapitulate briefly, manifestations of gross pathology and teratological defects occurred in 30 percent of 348 crania of adults and 18 percent of 73 juvenile crania (under age 18). Of 146 fairly complete skeletons (excluding crania), 40 per cent were affected by abnormalities, as were 6.1 per cent of 33 juvenile skeletons. Abnormal conditions found in the skull, in decreasing frequency were: auditory exostoses, traumatic lesions, inflammatory lesions of the glenoid fossa, osteoporosis, palatal abscess, syphilis (?), and fractures; males showed a markedly higher prevalence of auditory exostoses than females. The major kind of pathology found in the skeleton was inflammatory lesions of the long bones. Subdivision of the material by broad age groups indicates a generally greater incidence of pathology with advancing age, except cranial osteoporosis which is most prevalent in the juvenile crania. The frequency of pathology in individual bones of the skeleton is enumerated.

Statements made above are those of the writer and do not necessarily reflect the views of the U. S. Public Health Service.

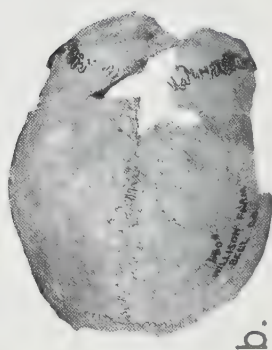
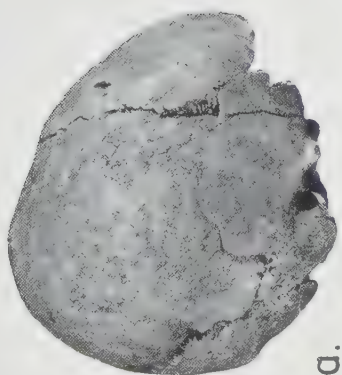
## LITERATURE CITED

- ANGEL, J. LAWRENCE 1947 The length of life in Ancient Greece. *J. Geront.*, 2: 18-24.
- GOLDSTEIN, MARCUS S. 1948 Dentition of Indian crania from Texas. *Am. J. Phys. Anthropol.*, 6: 63-84.
- 1953 Some vital statistics based on skeletal material. *Human Biology*, 25: 3-12.
- HOOTON, E. A. 1930 The Indians of Pecos Pueblo. A Study of Their Skeletal Remains. New Haven, Conn.
- HRDLICKA, A. 1935 Ear exostoses. *Smithsonian Miscell. Coll.* vol. 93, Smithsonian Institution, Washington, D. C.
- KRIEGER, A. D. 1946 The eastward extension of Puebloan dating toward cultures of the Mississippi Valley. *Am. Antiquity*, 12: 141-148, Part 1.
- KROGMAN, W. M. 1940 The pathologies of pre- and protohistoric man. *Ciba Symposia*, 2: 432-443.
- SIGERIST, HENRY E. 1943 *Civilization and Disease*. Cornell Univ. Press, Ithaca, N. Y.
- 1951 *A History of Medicine*. Oxford University Press.
- STEWART, T. D. 1940 Some historical implications of physical anthropology in North America (in *Essays in Historical Anthropology of North America*). *Smithsonian Miscell. Coll.* vol. 100, Smithsonian Institution, Washington, D. C.

## PLATE I

### EXPLANATION OF FIGURES

- (a) Syphilitic (?) lesions on parietal (Catalogue No. 417, Womack Farm, Lamar County).
- (b) Syphilitic (?) lesions on parietals (Catalogue No. 660 B, Willison Farm, Bell County).
- (c) and (d) Inflammatory lesions (syphilis ?) in skull and bones of same individual (Catalogue No. 411, Sanders Site, Lamar County).



## PLATE 2

### EXPLANATION OF FIGURES

- (a) Ulna with embedded end of arrowpoint (Catalogue No. 811j); Radius with foramen at neck (Catalogue No. 102); Inflammatory lesions of tibia and fibula, with ossification of one with other (Catalogue No. 20 v). All three specimens from Oso Site, Nueces County.
- (b) Large tumor on humerus (Catalogue No. 371, Sanders Site, Lamar County).
- (c) 1, Resorption of acromial end of clavicle (Catalogue No. 881, Bowie County); 2, Perforated sternum (Catalogue No. 758, Fate Bell Ranch, Val. Verde County); 3, Fused metatarsals of hand (Catalogue No. 174, Caplen Mound, Galveston County); 4, Unhealed fracture of ulna, forming a joint (Catalogue No. 36, Nueces County); 5, "Withered" humerus (Catalogue No. 662).
- (d) Resorbed neck of femur (possibly lost ?) and distal part of head of same femur, probably result of fracture. Other femur and innominate bone normal (Catalogue No. 757, Fate Bell Ranch, Val Verde County).







# PROBLEMS IN DETERMINING THE TOOTH ERUPTION SEQUENCE IN FOSSIL AND MODERN MAN <sup>1</sup>

STANLEY MARION GARN, KALEVI KOSKI <sup>2</sup>

AND ARTHUR B. LEWIS

*Fels Research Institute, Antioch College, Yellow Springs, Ohio*

FIVE FIGURES

## INTRODUCTION

The sequence of eruption of the permanent teeth has been extensively cited as distinguishing fossil hominids from recent man (Schultz, '50; Osman Hill, '54; Senyürek, '55). According to Schultz ('35, '44, '49, '50), early man is characterized both by precedence of the second molar over the premolars and late eruption of the canines, as exemplified in the sequence  $M_1 I_1 I_2 M_2 (P_1 P_2) C M_3$  or  $M_1 I_1 I_2 M_2 (P P) C M_3$ . In contrast, modern man or recent white man is described as having the  $P_2 M_2$  order and early eruption of the canines with a sequence that can be written as  $(M_1 I_1) I_2 (P_1 C P_2) M_2 M_3$  or  $(I_1 M_1) I_2 (PCP) M_2 M_3$ . Specifically, Weidenreich ('37) has claimed the  $M_2 P_2$  sequence for *Sinanthropus* and this latter sequence has also been attributed to several Neanderthaloids (Virchow, '20; Senyürek, '55). It is interesting therefore that Broom and Robinson ('50) after giving the sequence  $I_1 M_1 I_2 (C P_1) M_2 P_2 M_3$  feel "that it agrees closely with that of modern man."

Now the term "eruption" commonly refers to the cutting of the teeth through the gums, and the "eruption sequence"

<sup>1</sup> The research described in this publication was supported in part under grant No. M 1260 from United States Public Health Service.

<sup>2</sup> Visiting Smith-Mundt Fellow in Physical Growth, January-June, 1957. Present address: Institute of Dentistry, University of Helsinki, Helsinki, Finland.

given for living peoples is simply the order of appearance through the gums. However, this limited definition or eruption, and the usual method of determining the eruption sequence is hardly applicable to skeletalized material, human or subhuman, recent or fossil. And, unless potentially valuable data on the phylogeny of man are to be neglected, substitutes for eruption of the teeth through the gums (i.e. "gingival eruption") must be employed. Needless to say, data on the "eruption" sequences in fossil man are based on such substitutes.

One possible substitute for eruption through the gums is the order of calcification of the different teeth as seen in roentgenograms (cf. Garn, Lewis and Shoemaker, '56). This can be ascertained in the living, from recent skeletal remains, and in some cases from fossilized material if separated from the stony matrix. A second possible substitute for gingival eruption is the order of appearance of the tooth crowns out of the alveoli. This may be termed "alveolar eruption," and alveolar eruption can be determined radiographically, or from the direct observation of skeletalized material. And a third substitute is the order of attainment of the occlusal level, whether in the living or in skeletal remains. The use of tooth calcification is best exemplified in Rohklin's report on the dentition of the Teshik-Tash Neanderthal child from Uzbekistan (Rohklin, '49). Alveolar eruption has been considered by various authorities on the Neanderthals. Finally, the order of attainment of the occlusal level seems to have been an important criterion in determining the eruption sequence in some of the South-African man-apes, and in the Afalou child (Arambourg *et al.*, '34).

Invariably the assumption is made that these substitute sequences are either equivalent to, or identical with the order of appearance of the teeth through the gums. Certainly this assumption is implicit in the writings of Schultz (where alveolar eruption in primates is compared to gingival eruption in modern man) and in publications by Drennan ('32), Weidenreich ('37), Virchow ('20), Broom and Robinson ('51), and

Senyürek ('55) among others. However, this important assumption is rarely made explicit: only in Rohklin's analyses, to our knowledge, has it been spelled out. And while it is reasonable to assume that teeth emerge from the alveoli and cut the gum in the same order, major conclusions concerning phylogenetic trends have been made in the absence of data that prove or disprove the identity of the various measures of "eruption."

Suppose, for the moment, that the assumption of equivalence does not hold, and that the sequence of calcification is different from the order of gingival eruption, or that the order of alveolar eruption does not match the order of attainment of the occlusal level. In short, suppose that an individual may be  $M_2P_2$  if eruption is determined one way, and  $P_2M_2$  if it is determined another way. Thus, one might find apparent differences between fossil and modern man, differences due not to evolution, but to discrepancies between the criteria employed. Or, finally, suppose that some of the criteria of "eruption" have been incorrectly used, due to insufficient knowledge of normal calcification and variations in normal eruption. Here too, fossil man might be described as different from modern man, a difference due to errors in analysis and not to evolutionary progress. In the absence of definitive information on calcification and eruption, we now lack positive assurance that these hypothetical situations do not, in fact, obtain.

The present paper is primarily concerned with these several possibilities, and with the data necessary to explore them. It constitutes an analysis of the sequences of calcification and eruption of 255 contemporary American-born white children, with special attention to the problems of consistency and equivalence. While it is not assumed that the dental development of mid-western boys and girls necessarily parallels that of the subspecies and geographical races represented by early and middle-Pleistocene finds, it is obvious that the key



problems of equivalence and constancy (and related questions) can be approached in no other way.

#### METHODS AND MATERIALS

The present study is based upon serial longitudinal oblique-jaw roentgenograms of 255 white Ohio-born boys and girls collected over the period 1939-1957. The roentgenograms taken at 6-15 milliamperere seconds and at 50 PKV, showed the left mandibular molar and premolar row, generally without superimposition of the corresponding teeth on the right side. Although lateral-skull roentgenograms of the same children, taken at corresponding ages were routinely consulted during the investigation, they rarely contributed additional information due to superimposition of the teeth, and to the poorer definition in the dental area. Plaster casts of the dentitions were also employed, primarily in correlating clinical and roentgenographic appearances.

The population sample under consideration was almost exclusively of Northwestern European origin and comprised, for the most part, the kind of subjects commonly termed "Old American" by Hrdlička and others. As a group their dental health was good: professional care was both available and sought. Thus, only two individuals out of the entire sample used in the sequential studies experienced extraction of the mandibular first molar prior to ten years. Further, only 19 children exhibited either early loss or extensive crown destruction of the mandibular deciduous molars. These cases were included in the sample only after ascertaining that there were no systematic deviations in calcification or eruption of the permanent successors. Throughout, children with endocrinopathies, obvious developmental defects and children with incomplete records were excluded from consideration.

For each of the mandibular molar and premolar teeth, a record was made of the age corresponding to the earliest roentgenogram in which the following stages of tooth development were noted:

I. *Beginning calcification*: that is the last "follicle" stage prior to the first signs of cusp calcification.<sup>3</sup>

II. *Beginning root calcification*: that is the appearance of the floor to the pulp cavity or "bifurcation point" for molars, or the first signs of root calcification for premolars. (See text figures for illustrations.)

III. *Root completion*: that is complete closure of the apices.

IV. *Alveolar eruption*: that is elevation of the cusps above the margins of the alveoli (as defined by Schultz, '35).

V. *Attainment* of the occlusal level.

The roentgenograms themselves were taken at regular birthday and "half-birthday" visits to the Fels Research Institute, which were scheduled to narrow tolerance limits of  $\pm 6$  days. No interpolations were attempted between these six-month intervals. Only in a limited number of cases, where a routine roentgenogram was either lacking or incomplete was interpolation attempted, and then only to the standard six-month intervals. In all cases, the span of the records allowed careful evaluations. Questionable cases were resolved after referring to the preceding and succeeding roentgenograms in the series (cf. Garn, Lewis and Shoemaker, '56).

While it would have been possible to employ a larger number of stages (some workers having distinguished twelve or more for calcification alone) such a multiplicity seemed neither profitable nor desirable for the present study. The problem was not to develop norms, but to gain from data on living children, information both relevant and useful to the analysis of data on fossil children. Further, it was desirable to eliminate subjective estimates such as the proportion of the crown or root completed, since estimates of this kind cannot be made

<sup>3</sup> Since calcification may be demonstrated histologically before it is visible radiologically, this stage of development is properly a beginning calcification stage. However, for the two teeth considered, it may also be defined as the full follicle stage. Using the first signs of calcification as an index yields identical results, as far as the sequences are concerned, since there is an invariable relationship between the two.

reliably in the absence of sequential roentgenograms which can hardly be taken on fossils.

In assigning sequences, the orders  $P_2M_2$  or  $M_2P_2$  were given, only when the data were totally clear. For example, if root formation of  $M_2$  was noted well in advance of that for  $P_2$ , the sequence was written  $M_2P_2$ . When these two teeth appeared equally advanced, at a particular stage, this equality or "bunching" was indicated by the customary brackets as  $(P_2M_2)$ . Thus, the three possible sequences were  $P_2M_2$ ,  $(P_2M_2)$  and  $M_2P_2$ .

Inasmuch as the investigative problem was that of pattern consistency, only the simplest statistical procedures were used. For the most part the question was what proportion of children were changed or unchanged in sequence from one stage to the next. No correction was made for the fact that not all children were represented at all stages: this is an inevitable consequence of a longitudinal study with continuing recruitment. However, statistical problems resulting from dropping-out of subjects, or dropping-out and subsequent re-entry, could be neglected. Loss due to "attrition" in the Fels Longitudinal Studies is of the order of 1% and is too small to have any effect on the shifting proportions of the different sequences observed from one stage to the next.

#### FINDINGS

The problem of consistency of sequence during tooth calcification and eruption was first investigated cross-sectionally by computing the proportion of Fels children who were rated  $P_2M_2$ ,  $(P_2M_2)$  or  $M_2P_2$  at each of the five stages previously described. This approach, which made maximum use of the data from over 3000 serial oblique-jaw roentgenograms consulted during the study was designed to answer one question: were the proportions of these three sequences approximately constant throughout the five stages of calcification and eruption?

As shown in table 1, there was immediate presumptive evidence that such consistency was not the general rule. In stage

I (beginning calcification) the  $P_2M_2$  sequence was observed in approximately one-third of 178 boys and girls. However, by stage II (beginning root calcification) approximately three-fourths of 151 cases were  $P_2M_2$ . And, in the final calcification stage (apical closure) the  $M_2P_2$  sequence, least common to begin with, was lacking entirely, possibly a chance event in the present sample. Turing to stage IV (alveolar eruption)

TABLE 1

*Variations in the proportion of children with the sequence  $P_2M_2$ , ( $P_2M_2$ ) and  $M_2P_2$  during calcification and eruption*

STAGE	$P_2M_2$				$(P_2M_2)$				$M_2P_2$			
	BOYS		GIRLS		BOYS		GIRLS		BOYS		GIRLS	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
I												
Beginning												
Calcification	35	36	24	30	50	51	40	50	13	13	16	20
II												
Beginning												
root formation	58	72	53	75	18	23	14	20	4	5	4	5
III												
Apical closure	7	53	10	83	5	42	2	17	-	-	-	-
IV												
Alveolar												
eruption	9	30	10	33	7	23	9	35	14	47	7	27
V												
Occlusal												
level	9	45	11	73	6	30	3	20	5	25	1	7

the  $M_2P_2$  sequence was fairly common, and finally in the order of attaining the occlusal level the  $P_2M_2$  stage was again the most common. Clearly, the proportion of children with the different eruption sequences varied from stage to stage, a finding that could not be attributed to differential sampling, since the data employed here were longitudinal in nature. Moreover, the  $M_2P_2$  sequence was most common in alveolar eruption, a finding of considerable importance since alveolar eruption is commonly used as the measure of "eruption" in studies involving skeletal material.

Considering only the  $M_2P_2$  sequence, because of its alleged prevalence in fossil man, the proportions of individuals exhibiting this sequence at each of the five stages of calcification and eruption were graphed as shown in figure 1. Using a simple non-parametric test for significance (chi-squared) with appropriate corrections for continuity, it was considered unlikely that the shifting proportions of the  $M_2P_2$  sequence could be due to chance alone.

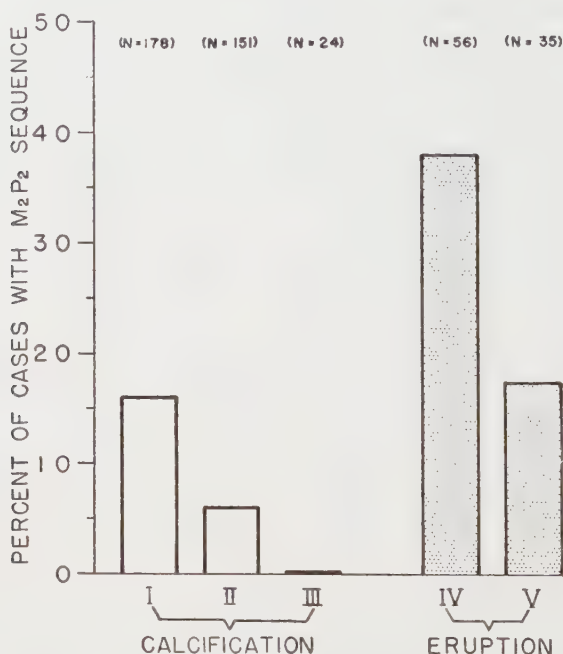


Fig. 1 Variations in the proportion of children with the  $M_2P_2$  sequence at different stages of tooth calcification (left) and eruption (right). The  $M_2P_2$  sequence is more common when alveolar eruption is considered, and least common in the later stages of calcification.

With this indication that the proportion of children  $P_2M_2$  ( $P_2M_2$ ) or  $M_2P_2$  varied from stage to stage, attention was then centered on longitudinal analyses of the data. The sequence for each child was compared, stage by stage, using every combination of stages, with a view to determining whether the sequence was likely to change.



TABLE 2

*Proportion of children changing sequence from one stage to another*

COMPARISON OF STAGES	$P_2M_2$		$(P_2M_2)$		$M_2P_2$		TOTAL	
	No.	%	No.	%	No.	%	No.	%
I and II*								
Changed	3	11	49	82	10	59	62	59
Unchanged	25	89	11	18	7	41	43	41
I and III								
Changed	0	0	10	83	6	100	16	69
Unchanged	5	100	2	17	0	0	7	31
I and IV								
Changed	8	50	16	67	1	25	25	57
Unchanged	8	50	8	33	3	75	19	43
I and V								
Changed	3	30	12	75	2	50	17	57
Unchanged	7	70	4	25	2	50	13	43
II and III								
Changed	3	20	1	50	4	100	8	38
Unchanged	12	80	1	50	0	0	13	62
II and IV								
Changed	19	59	8	80	0	0	27	60
Unchanged	13	41	2	20	3	100	18	40
II and V								
Changed	6	27	2	33	1	33	9	29
Unchanged	16	73	4	67	2	67	22	71
III and IV								
Changed	8	80	2	100	0	0	10	83
Unchanged	2	20	0	0	0	0	2	17
III and V								
Changed	4	44	2	100	0	0	6	54
Unchanged	5	56	0	0	0	0	5	46
IV and V								
Changed	0	0	5	62	11	65	16	47
Unchanged	9	100	3	38	6	35	18	53

\* Stages I-V as in table 1.

Table 2, which records all combinations of stages possible with the present data, contains revealing information on individual changes in "eruption" sequence; the 168 children included in the longitudinal analyses exhibited a marked ten-

dency to change sequence. Change, however, was least likely to occur from the  $P_2M_2$  sequence. Out of 156 combinations of stages involving the  $P_2M_2$  sequence as the earlier, a change to  $(P_2M_2)$  or  $M_2P_2$  was observed in only 35%. In contrast, of 142 combinations involving the  $(P_2M_2)$  sequence as the earlier, 75% shifted sequence to  $P_2M_2$  or  $M_2P_2$ . And for children with the  $M_2P_2$  sequence at any stage, more than half (60%) of 58

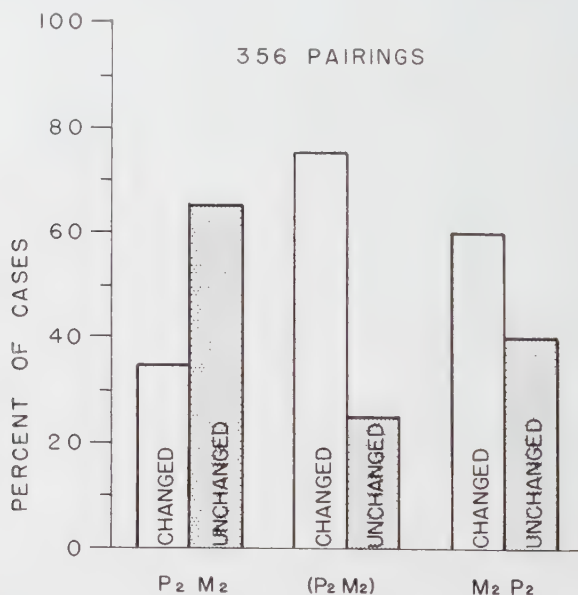


Fig. 2 Probability of changing sequence during tooth calcification and eruption. Children  $P_2M_2$  at any stage are more likely to remain  $P_2M_2$  in subsequent stages, whereas children with the  $(P_2M_2)$  or  $M_2P_2$  sequences are more likely to change than to remain the same.

pairings shifted to  $(P_2M_2)$  or  $P_2M_2$ . More than half of the 356 combinations tended to change (196 or 55%), whereas only 45% or 160 remained *unchanged* from one stage to another. While changes from  $P_2M_2$  to  $M_2P_2$ , and from  $M_2P_2$  to  $P_2M_2$  were both observed, it was clear that the  $M_2P_2$  sequence was least likely to persist, and the  $P_2M_2$  sequence most likely to persist. Again, the data emphasized the transient nature of the  $M_2P_2$  sequence.

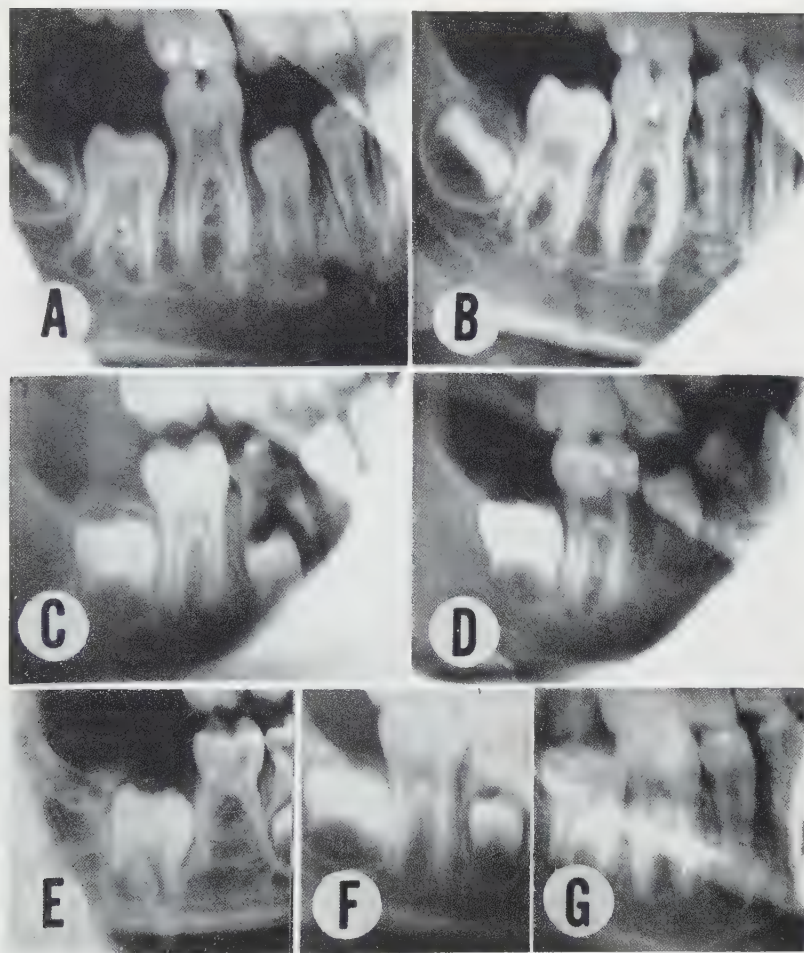


Fig. 3 Roentgenograms showing variations in sequence during calcification and eruption. A and B: change from the ( $P_2M_2$ ) sequence in alveolar eruption at 11 years to the  $P_2M_2$  sequence in attaining the occlusal level at 12 years (Fels case No. 260). C and D: differential rates of travel of  $P_2$  and  $M_2$  between 8-1/2 and 9 years. In six months the deciduous predecessor of  $P_2$  has been shed and the crown of  $P_2$  has passed beyond clinical eruption, yet the level of  $M_2$  has changed but little (case No. 329). E, F and G: changes in sequence from  $M_2P_2$  in early crown calcification at 8-1/2 years to  $P_2M_2$  at the attainment of the occlusal level at 11-1/2 years (case No. 211).

Since the  $M_2P_2$  sequence was most common in the alveolar eruption stage (stage IV in the present system), and since the  $M_2P_2$  sequence in alveolar eruption has been claimed as "characteristic" of fossil man, a further analysis of alveolar eruption was indicated. This involved careful scrutiny of all available roentgenograms at and about the alveolar eruption stage, and analysis of the events succeeding alveolar eruption and up to the time of attainment of the occlusal level.

It was apparent that loss of alveolar substance over the crown of  $M_2$  was not immediately followed by alveolar eruption, that is, the emergence of the crown or elevation of the

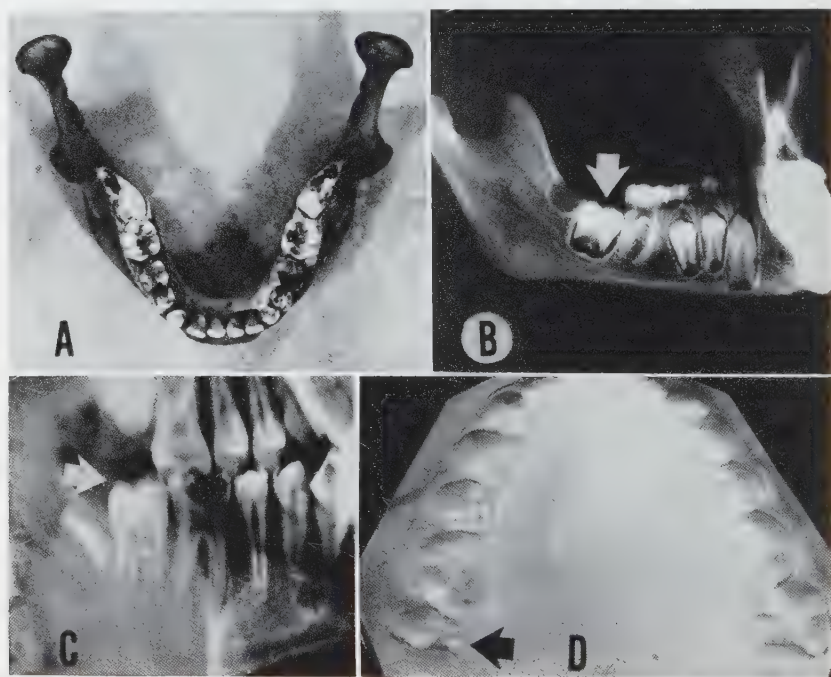


Fig. 4 Examples of possible errors in determining the "eruption" sequence. A, mandible showing  $M_2$  in crypt,  $P_2$  not yet erupted; this suggests the  $M_2P_2$  eruption sequence. B, skiagram of the same mandible showing that  $M_2$  has not yet reached alveolar eruption, and  $P_2$  is more advanced in calcification. The true sequence *at this stage* would be  $P_2M_2$ . C, roentgenogram showing  $M_2$  apparently fully erupted at 11-1/2 years. D, cast made of same subject (Fels No. 87) one-half year later;  $M_2$  is still incompletely erupted clinically, and a  $P_2M_2$  sequence of gingival eruption would be assigned.

cusps above the alveolar level. On the contrary, *one to two* years generally elapsed between the two events. These observations based on some 29 cases indicated that a second mandibular molar already visible in a cleaned and macerated or fossilized and restored specimen need not be "ready to erupt" (see figure 4a). Clearly one could not assign the  $M_2P_2$  sequence to any mandible where the crown of  $M_2$  was visible in the crypt, as our serial roentgenograms prove without doubt. Yet, such an error has been repeated many times in interpreting remains (cf. Senyürek, '55).

Finally, the shift from  $M_2P_2$  at alveolar eruption to  $P_2M_2$  at the time of attaining the occlusal level was explained by reference to the vastly different eruption rates of  $P_2$  and  $M_2$ . It is rather common for  $M_2$  to precede  $P_2$  in alveolar eruption, yet for  $P_2$  to attain the occlusal level before  $M_2$ . But the mandibular second premolar travels further and faster, moving from alveolar eruption to the occlusal level in 9.6 months (in the female) and 11.0 months in the male, whereas  $M_2$  (which erupts from the alveoli at or near the occlusal level) requires 14.8 months on the average in the female and 15.6 months in the male.

Figure 5 which summarizes the elapsed time from alveolar eruption to attainment of the occlusal level in 30 boys and girls not only shows how the shift in sequence can occur, as a result of normal differences in the rate of eruption, but casts further light on the all-important difference between alveolar eruption and gingival eruption. For in the second mandibular molar, alveolar eruption may be far from gingival eruption: though protruding through the alveoli, the cusps are still well covered by the gums. Alveolar eruption for the second premolar, on the other hand, is close to gingival eruption. Thus, an unquestioned  $M_2P_2$  sequence in alveolar eruption need not be presumptive evidence of an  $M_2P_2$  sequence in gingival eruption. In other words, in a given specimen, fossil or recent, where the cusps of  $M_2$  are above the alveolar surface and those of  $P_2$  not, we would still be per-



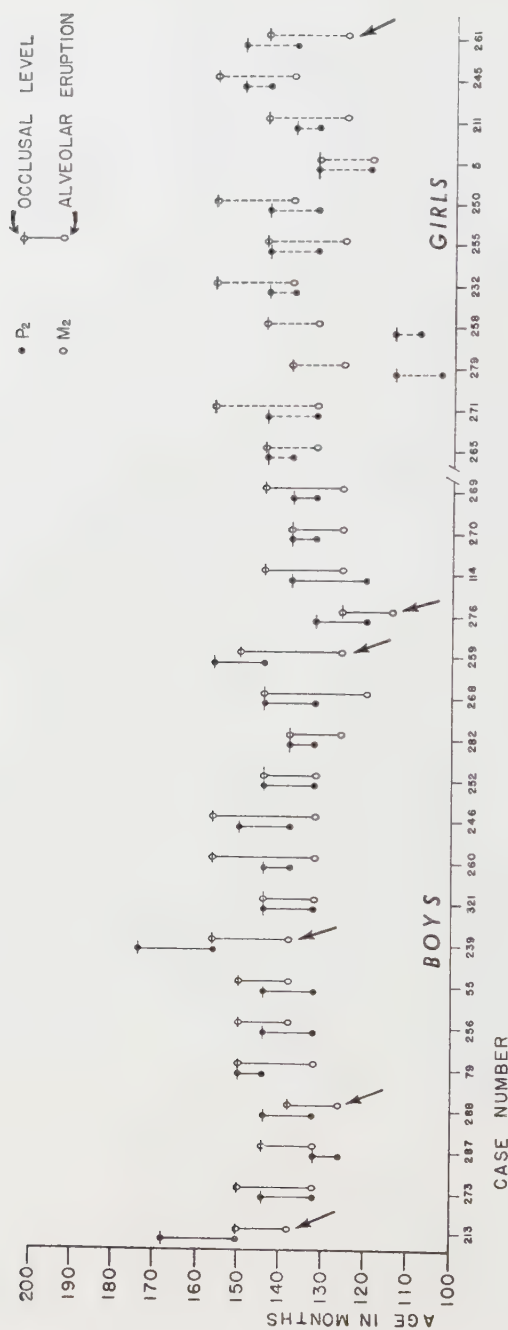


Fig. 5 Duration-of-eruption data for 30 boys and girls. Although 17 were  $M_2P_2$  in alveolar eruption, only 6 (indicated by arrows) remained  $M_2P_2$  in reaching the occlusal level. Since  $P_2$  becomes clinically visible at the time of alveolar eruption, whereas gingival eruption of  $M_2$  does not take place until long after alveolar eruption, in most cases the sequence of gingival eruption will be  $P_2M_2$  regardless of the order of appearance from the alveoli.

petrating an error if we were to argue that gingival eruption would have proceeded in the same relative order.

Clearly, then, the present data analyzed both cross-sectionally and longitudinally do not lend support to the assumption that the several substitute sequences are either equivalent to gingival eruption, or equivalent to each other. Rather, they support the alternative suppositions, and the possibility that at least some of the conclusions on the alleged differences between fossil and modern man are not differences at all. With the evidence that the  $M_2P_2$  sequence is especially common at the time of alveolar eruption, it is easy to see how skeletal remains of the present population might be erroneously listed as having the  $M_2P_2$  eruption sequence and therefore "different from recent white men."

#### DISCUSSION

The findings in this study are sufficiently clear-cut and their implications so obvious that rather little in the nature of a discussion is needed. The sequence of calcification and eruption of the permanent teeth is by no means constant within an individual: it is therefore somewhat hazardous to guess from the sequence at one stage, what the probable sequence would have been at another stage. Moreover, it is distinctly unwise to compare the eruption sequence at one stage in a particular fossil, to the sequence at another stage in a second fossil or in living man.

The  $M_2P_2$  sequence said to be "characteristic of fossil man" is often used to set off paleanthropic hominids from contemporary whites. But the eruption sequence as commonly determined from fossils or skeletalized material is the order of alveolar eruption, whereas eruption for living individuals ordinarily refers to gingival eruption. If the order of alveolar eruption on contemporary white children is alone considered, the  $M_2P_2$  sequence exists in a rather high proportion of cases. Thus, the apparent distinction between fossil and contemporary man tends to disappear. To state the findings some-

what differently, at least half of these modern children have a "fossil" eruption sequence!

Throughout calcification and eruption the prevailing tendency is to shift sequence, a trend more characteristic of the  $M_2P_2$  sequence than for the  $P_2M_2$  order. Thus, some fossil or recent child, correctly diagnosed at  $M_2P_2$  at one stage, might have proven  $P_2M_2$  at the time of gingival eruption. And, since the  $P_2M_2$  order can become  $M_2P_2$ , even Rohklin's cautious statements about the probable sequence of gingival eruption in the Teshik-Tash child may be in error, though the evidence and the probabilities strongly favor his opinion.

Moreover, there are numerous opportunities for error in determining the eruption sequence, especially if the position of the mandibular second molar is used as a diagnostic criterion. During calcification  $M_2$  lies close beneath the surface of the alveolar process; in a weathered or worn mandible the crown may be exposed to view. Yet this does not mean that the tooth is about to erupt; it is simply the normal position for a calcifying second molar. Again, even when the cusps of  $M_2$  project above the surface of the alveolus this position is not equivalent to gingival eruption. Together there are many opportunities to make an incorrect diagnosis of the  $M_2P_2$  sequence.

In a previous paper (Garn, Lewis and Shoemaker '56) we challenged the notion of an abrupt shift from the  $M_2P_2$  sequence in fossil man to the  $P_2M_2$  sequence in modern man, and suggested instead a simple shift in the proportions of the two sequences, which appear to be under genic control, if sibling data are taken into account. However, with the present data at hand, and noting the all-important difference between alveolar eruption and gingival eruption, we may now question even our own supposition that such a shift has happened. Using the same "eruption" stages (since the assumption of equivalence has proved to be untenable) it is now doubtful that fossil and modern man differ materially in the order of eruption of the teeth.

Admittedly, data on contemporary white children need not be fully applicable to fossil man, or to non-whites. By way of example, American Indians (Pima and Apache) are generally  $M_2P_2$  in gingival eruption (Hrdlička '08). It is possible that Neanderthaloids  $M_2P_2$  in alveolar eruption remained  $M_2P_2$  in gingival eruption far more often than is true for contemporary whites. However, the present data do serve to question the assumption of equivalence or identity of the various measures of eruption, and therefore many of the conclusions concerning the eruption sequence in now-extinct forms of man.

Unless fossil man were more consistent than we are during calcification and eruption, and unless all of the  $M_2P_2$  diagnoses were correctly made (and this we have reason to doubt), it is questionable whether the  $M_2P_2$  sequence of gingival eruption was the prevalent one as is so often claimed. Even for alveolar eruption, at which stage modern Ohio children are so often  $M_2P_2$ , we doubt whether the  $M_2P_2$  sequence was invariable in paleanthropic man (cf. Rohklin '49). Thus, there is no absolute difference between the fossils and us in regard to eruption, or even a statistical gap for that matter. And, therefore, using the order of eruption of the molar and premolar teeth as a taxonomic criterion now seems decidedly unwise.

#### SUMMARY

1. Serial oblique-jaw roentgenograms of 255 white Ohio-born boys and girls were examined in an effort to determine whether the  $M_2P_2$  sequence, claimed to be characteristic of fossil man might be due to the limitations of the material used.

2. Analyzing the data cross-sectionably, it was evident that the proportion of children with the  $P_2M_2$  ( $P_2M_2$ ) and  $M_2P_2$  sequences fluctuated widely from one stage of calcification or eruption to another. Thus, the sequence at one stage could not be used to predict the sequence at another stage.

3. Longitudinal analyses of the data confirmed the indication of inconstancy of sequence. Out of 356 pairs of stages, change was observed in 196 (55%). At each stage children

with the  $M_2P_2$  sequence were more likely to change: children with the  $P_2M_2$  sequence were more likely to remain unchanged.

4. The highest proportion of cases with the  $M_2P_2$  sequence (38%) was observed in the stage of alveolar eruption. However, because of rapid eruption of  $P_2$ , most children  $M_2P_2$  in alveolar eruption became  $P_2M_2$  at the time of clinical eruption. Thus, fossils with a *bona fide*  $M_2P_2$  sequence in alveolar eruption need not have been  $M_2P_2$  in clinical eruption.

5. It was further evident that the  $M_2P_2$  sequence might be erroneously diagnosed in skeletalized or fossilized material, if the visibility of the crown of  $M_2$  in the crypt was used as an indication of "eruption." This error together with the actual frequency of the  $M_2P_2$  sequence at alveolar eruption would lead to an apparent predominance of the  $M_2P_2$  sequence in *any* skeletal population.

6. On the basis of these findings, it is questionable whether the  $M_2P_2$  eruption sequence was truly more characteristic of fossil children than of contemporary juveniles.

#### ACKNOWLEDGMENTS

The authors acknowledge their indebtedness to Mr. Demarest Polacheck for statistical assistance; Professor Joseph B. Homan of the University of Cincinnati for positive reproductions used in figures 3 and 4; Dean Leroy R. Boling of the Washington University School of Dentistry for the photograph and skiagram of the mandible shown in figure 4; and to Dr. Lina Landkof for translations from the Russian. Miss Ruth Bean arranged the scheduling of the children within extremely close tolerance limits. Mrs. Lois Conklin assisted in the manuscript preparation.

#### LITERATURE CITED

- ARAMBOURG, C. M., M. BOULE, H. VALLOIS AND R. VERNEAU 1934 Les grottes paléolithiques des Beni Segoual (Algerie) Arch. Inst. Paleolith. Humaine. Memoire, 12 pp. 139-147.
- BROOM, R., AND J. T. ROBINSON 1951 Eruption of the permanent teeth in the South African fossil ape-men. Nature, 167: 443.



- DRENNAN, M. R. 1932 L'ordre d'éruption des dent permanentes chez les Boschimans. *L'Anthropologie*, 42: 491-495.
- GARN, S. M., A. B. LEWIS AND D. W. SHOEMAKER 1956 The sequence of calcification of the mandibular molar and premolar teeth. *J. Dent. Res.*, 35: 555-561.
- HRDLÍČKA, A. 1908 Physiological and medical observations among the Indians of Southwestern United States and Northern Mexico. Smithsonian Institution, Washington (Bur. Am. Ethnol. Bull. No. 34).
- OSMAN-HILL, W. C. 1954 Man's ancestry: a primer of human phylogeny. C. C. Thomas, Springfield, Ill.
- ROHKLIN, D. G. 1949 Certain data from a roentgenological examination of the child skeleton from the cave of Teshik-Tash, Southern Uzbekistan. pp. 109-113 in Gremiatski, M.A. (ed.) Teshik-Tash: Palaeolithic Man, Moscow State University, Moscow.
- SCHULTZ, A. H. 1935 Eruption and decay of the permanent teeth in primates. *Am. J. Phys. Anthrop.*, 19: 489-581.
- 1944 Age changes and variability in gibbons. *Am. J. Phys. Anthrop.*, n.s. 2: 1-129.
- 1949 Ontogenetic specializations of man. *Arch. d'Julius Klaus-Stiftung*, 24: 197-216.
- 1950 The physical distinctions of man. *Proc. Am. Phil. Soc.*, 94: 428-449.
- SENYÜREK, MUZAFFER 1955 A review of the order of eruption of the permanent teeth in fossil hominids. *Türk Tarih Kurumu Belleten*, 19: 407-44.
- VIRCHOW, HANS 1920 Die menschlichen Skeletreste aus dem Kämpféschen Bruch im Travertin von Ehringsdorf bei Weimar. Gustav Fischer, Jena.
- WEIDENREICH, F. 1937 The dentition of *Sinanthropus pekenensis*: a comparative odontography of the hominids. *Palaeontologica Sinica*, n.s. 1: 120-180.



# GALVANIC SKIN RESPONSE IN MONKEYS WITH PREHENSILE TAILS<sup>1</sup>

PETER A. STEWART, RICHARD P. SMITH, ISAAC BEHAR,  
AND ARTHUR J. RIOPELLE

*Departments of Physiology and Psychology, Emory University  
Emory University, Georgia*

TWO FIGURES

## INTRODUCTION

The Galvanic Skin Response or Galvanic Skin Reflex (GSR) is a change in the electrical resistance of mammalian skin, with a characteristic time course, which occurs as an autonomic response to a variety of stimuli, usually of alerting or threatening character. The resistance shows an initial rapid decrease, typically within three seconds of stimulation, followed by a gradual return to approximately its initial value (fig. 1). These resistance changes are generally attributed to changes in sweat gland activity resulting from a specific pattern of autonomic response to the stimulus, although the cellular mechanisms resulting in the resistance changes have not yet been elucidated.

GSR's have been recorded from the palmar and plantar surfaces of several mammals, including rats, dogs, cats, monkeys, and man (Woodworth and Schlosberg, '54). In man it is possible to record these resistance changes from many skin areas, but in other mammals only the foot pads, or palmar and plantar surfaces, have been shown to exhibit GSR's. That the specific pattern of increased sweat gland activity which results in the palmar and plantar GSR is not directly related to temperature control has been well established. Darrow ('36) has

<sup>1</sup> Supported in part by a grant (M-589) from the National Institute of Mental Health of the National Institutes of Health, Public Health Service.

suggested that the response serves a useful purpose in preparation for emergency situations where surety of grasp is essential.

The tails of several genera of the monkey family Cebidae are markedly prehensile, and are used extensively in grasping and locomotion. The spider monkeys, genus *Ateles*, possess particularly well developed prehensile tails, the external anatomy of which has been described in detail by Pocock ('20). The

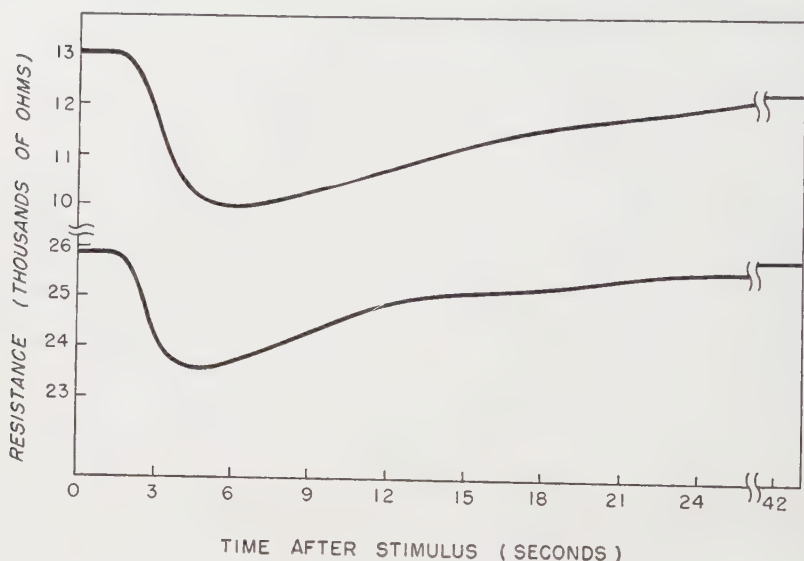


Fig. 1 Typical GSR's, from spider monkey "Sad Sack": Top curve, from plantar surfaces; bottom curve, from tail pad.

tail pad, an area of naked skin on the lower surface, closely resembles the palmar and plantar areas, even to the presence of dermatoglyphs. In view of the obvious morphological similarity of the tail pad to palmar and plantar skin, and the extensive use of these tails in grasping, similarities in reflex response might be expected on the basis of the "preparation for grasping" notion. Accordingly, we have attempted to record GSR's from the tail pads of spider monkeys, *Ateles geoffroyi*. For comparative purposes, we have also attempted

to record from the tails of two other genera, *Macaca cynomolgus* (= *irus*) and *Cebus albifrons*. The *Cebus*' tail is definitely prehensile but has no tail pad. The *cynomolgus*' tail is not prehensile and has no tail pad.

#### METHODS

The animals were restrained in a specially constructed wooden chair. The tail was shaved if necessary, and immobilized on a narrow board to minimize movement artefacts. The tail recording electrodes consisted of convenient lengths of heavy tinned copper wire buried on one-inch foam rubber pads, kept moist with salt solution and tied to the tail three inches apart. They were large enough to eliminate possible artefacts due to callouses, although none of the animals had visible callouses. The stimulating electrodes were similar, and were placed on palmar or plantar surfaces, or on the skin of the lower leg, as convenient. Skin resistance was measured in a conventional bridge circuit and recorded on either a Brown recording potentiometer or a Sanborn recorder. An electronic stimulator provided 60/sec. square wave pulses. An electronic timing circuit connected the stimulus to the animal for 0.2 seconds and turned on the recorder chart drive motor simultaneously. Stimulus intensity ranged from 2 to 17 volts. Each animal was subjected to approximately three shocks at each of 5 intensity levels. The subjects were: 3 spider monkeys, 2 adult and one immature; 3 young adult cebus monkeys; 1 young adult cynomolgus monkey. Some records were also taken under light ether anesthesia, and at different times, after dosing with atropine or pilocarpine.

#### RESULTS

1. GSR's indistinguishable from those at palmar or plantar sites were obtained from the tail pads of all three spider monkeys. Typical records are shown in figure 1. The amplitude of the tail response varied with stimulus strength as indicated in figure 2. This is characteristic of palmar and plantar GSR's



(Hovland, '40). The base skin resistance of the tail pad was usually about 20,000 ohms, and decreased approximately 10% during the test period. Similar characteristics were observed during palmar and plantar recordings from these monkeys.

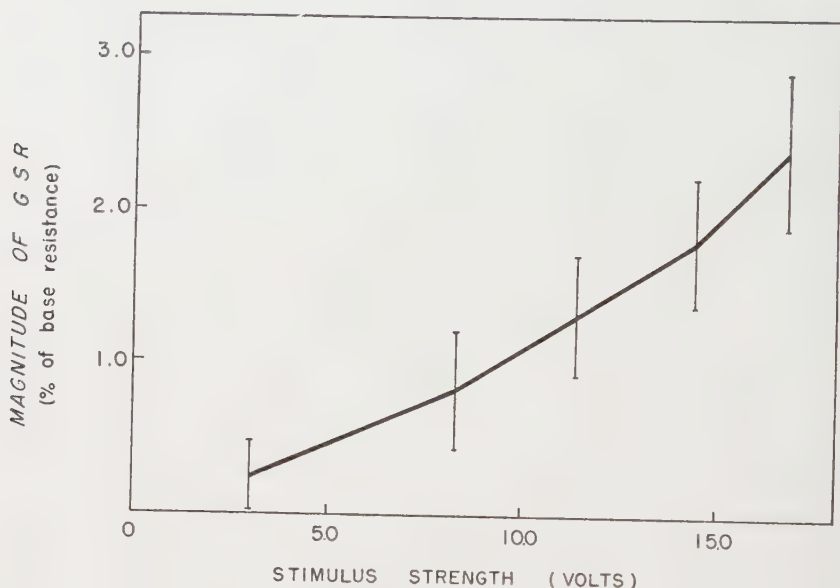


Fig. 2 Variation in magnitude of tail pad GSR with stimulus strength. Average values for three trials each on three spider monkeys. Vertical bars indicate standard deviations.

2. Although characteristic palmar and plantar GSR's were easily obtained from the cynomolgus monkey, no resistance changes could be detected in the tail, regardless of stimulus intensity. The base resistances at the plantar areas ranged from 8,000 to 14,000 ohms.

3. No skin resistance changes could be recorded from the tails of any of the cebus monkeys.

4. No GSR's could be recorded from palmar or plantar sites in any of the cebus monkeys. The base resistance was always very low and showed none of the characteristic slow changes obtained in other genera.

## DISCUSSION

The existence of a typical GSR in the tail pad of the spider monkey tends to support the "preparation for grasping" explanation of the function of this response, since this animal uses his tail essentially as a fifth limb in locomotion, in grasping objects, and in feeding.

The tail of the cynomolgus monkey is not prehensile and has no specialized tail pad; it is used primarily for extra support when the animal is standing erect. In the cebus monkey, on the other hand, while the tail is prehensile, it is used chiefly as an organ of static support. While being held, a cebus monkey will tightly coil his tail around the arm of his captor, and can support his body weight easily this way. However, he does not use his tail extensively for grasping objects, nor as a dynamic organ of locomotion.

The data from the tails of these three different genera therefore suggest that GSR's occur in mammals (other than man) in regions whose important function is grasping, and that Darrow's "preparation for grasping" explanation of the function of the GSR is correct.

The absence of a GSR anywhere on the cebus monkey is difficult to understand. No data have been found in the literature on the histology of the palmar and plantar skin in this animal, but superficial observation discloses no striking differences between this skin and that of the other monkeys, other than pigmentation. We noticed during the first few test periods that when these monkeys returned to their cages they were exhausted and unable to climb to their perches, although they had not seemed unusually excited while restrained in the testing chair. To eliminate this physical exhaustion as the factor responsible for the lack of GSR, in subsequent trials the animals were removed from their cages as quickly as possible, and then lightly etherized, to the point of minimal spontaneous movement. They were kept in this condition until secured in the test chair. The level of anesthesia was then varied from unconsciousness to normal alertness, but still no palmar or plantar GSR's could be recorded. With this treat-

ment, the animals showed no signs of physical exhaustion when returned to their cages. As a control on the effects of anesthesia on the GSR, a cynomolgus monkey was treated similarly. Normal plantar GSR's were recorded at very light levels of etherization. The GSR disappeared at deeper levels, and returned as the anesthesia wore off. The lack of GSR in the cebus monkey can therefore not be attributed to either physical exhaustion or the effects of the ether.

In view of the remarkably low palmar base resistance in the cebus monkeys, as well as the lack of GSR, base resistances were measured with these animals atropinized, (0.5 mg per kg. body wt.). At this dose, atropine has the effect of blocking the sympathetic control of sweat gland activity. The skin resistance should therefore rise to very high levels, and

TABLE 1  
*Palmar base resistances of cebus monkeys, typical values. (in ohms)*

	CEBUS NO. 1	CEBUS NO. 2	CEBUS NO. 3
Control (No drugs)	5900	7000	6400
Pilocarpine, 1 mg/kg	5700	4800	4700
Atropine, 0.5 mg/kg	8000	8000	6800

no GSR should be seen. In the atropinized cebus monkeys, very dry palmar and plantar skin accompanied by a rise of resistance was found, but even under these conditions the resistance was unusually low compared with other mammals (table 1). Pilocarpine, a sympathomimetic drug, which should have the opposite effect to atropine, was administered to these animals in another series of tests, and had the expected result of producing copious palmar and plantar sweating, but only a small decrease in skin resistance, and again, no GSR could be observed.

We conclude from these results that palmar-plantar skin, including the sweat glands, is peculiar in the cebus monkey, and subject to only limited nervous and pharmacological control. It may also be that the electrical resistance of the skin is determined primarily by some factor other than sweat gland

activity. More data on the histology, pharmacology, and neurophysiology of this species are needed to settle this question.

#### SUMMARY

Measurement of Galvanic Skin Response (GSR) to electric shock was attempted on palmar, plantar and tail surfaces of spider, cynomolgos and cebus monkeys. Typical GSR's were obtained from palmar and plantar surfaces of spider and cynomolgos monkeys. The spider monkeys' tail pads also showed characteristic GSR's. No GSR's could be elicited from the tails of the cynomolgos or cebus monkeys. These results support Darrow's suggestion that the function of the GSR is to prepare the appropriate surface for efficient grasping in emergency situations.

It was also found that no GSR could be obtained from palmar or plantar surfaces of the cebus monkeys. Their basal skin resistances were abnormally low, and atropine and pilocarpine produced only small changes. The reason for the absence of a GSR in this species is unknown.

#### LITERATURE CITED

- DARROW, CHESTER W. 1936 The Galvanic Skin Reflex (sweating) and Blood Pressure as Preparatory and Facilitative Functions. *Psychol. Bull.*, 33: 73-94.
- HOVLAND, C. I., AND A. H. RIESEN 1940 Magnitude of Galvanic and Vasomotor Response as a Function of Stimulus Intensity. *J. Gen. Psychol.*, 23: 103-121.
- POCOCK, R. I. 1920 On the External Characters of the South American Monkeys. *Proc. Zoo. Soc. Lond.*, 90: 91-113
- WOODWORTH, R. S., AND HAROLD SCHLOSBERG 1954 *Experimental Psychology*, revised edition, Henry Holt and Co., N. Y., Chapter 6, pp 133-158.





# THE DISTRIBUTION OF ABO BLOOD GROUPS IN A SAMPLE OF HOSPITAL PATIENTS RECEIVING BLOOD TRANSFUSIONS

JOHN BUETTNER-JANUSCH

*Laboratory of Physical Anthropology, University of Michigan*

At the present time there is great interest in efforts to increase our understanding of the nature of the selective agents which act on the ABO blood group system. Brues ('54) presents many of the arguments in support of the view that the ABO genes are subject to natural selection. The foundations for work on the physiological functions of this genetic system and the selective mechanisms that operate on it were laid many years ago by investigators such as Ehrlich and Morgenroth ('00) and Dienst ('05). Dienst proposed that eclampsia was due to antagonism between the blood of the fetus and its mother. He compared the process resulting in eclampsia to blood transfusions between different mammalian species. The response to this idea was typified by Liepmann ('05) who declared that this was a "biological monstrosity." It was unthinkable that a mother's blood would damage the child she was carrying.

Since the Hirzsfelds ('19) demonstrated that there are differences in ABO frequencies among various populations and racial groups, the discovery of more differences in population ABO frequencies and their use as racial criteria have become anthropological traditions. The literature contains reports of the ABO distribution in thousands of human groups, based on samples ranging in size from fifty to over two hundred thousand. Yet none of these studies describes the ABO frequencies with respect to the age and sex composition of the population tested. Glass ('54) points out that

most of these investigations not only fail to group the data by age or sex but also they are usually not based upon random samples. Yet such data and analyses are essential if selection on a genetic system is to be demonstrated. Furthermore, we seldom find information about the physical fitness or demographic status of the individuals tested. An examination of Boyd's famous compilation ('39) shows that there are differences in frequencies of the four ABO phenotypes in groups taken from mental hospitals, tuberculosis sanatoria, and military recruiting offices. Boyd's sources, however, do not give sufficient information about the condition of the individuals so hospitalized or recruited to warrant further analysis. It seems reasonable to conclude that most investigators excluded the possibility that selection exists from their approach to the ABO system (*e.g.*, Manuila, '56).

The importance of the ABO system to forensic medicine and its apparent usefulness in racial classifications are probably further reasons that this system has been regarded as resistant or immune to selection. Its immutability and stable properties have been emphasized repeatedly by physicians and anthropologists (Verzar, '22). Another factor has been the emphasis by anthropologists on the use of non-adaptive traits, that is, traits not subject to selection, as racial markers. Boyd ('53), among others, discusses the difficulties the concept of non-adaptive traits make for sound evolutionary theory.

This report describes an analysis of the ABO blood group distribution in a large sample of hospital patients, which was undertaken in order to discover if, in fact, sick people differ from others with respect to the ABO frequencies. We reversed the usual study in which donors to a blood bank are analyzed and instead took for our sample the persons receiving transfusions.

The results have implications for understanding of the mechanisms of selection on the ABO system and for the use of the ABO blood group frequencies in anthropological studies.

## ACKNOWLEDGMENTS

This study was supported, in part, by a grant from the Horace H. Rackham School of Graduate Studies of the University of Michigan. F.P. Thieme secured IBM statistical machines with which to analyze the data. W. J. Schull provided invaluable advice on statistical methods. J. V. Neel assisted in obtaining critical hospital records. The personnel of the blood bank and the tabulating service of University Hospital, Ann Arbor, Michigan, co-operated in the collection of the data.

## MATERIALS AND METHODS

Relevant data were recorded for all in-patients who received blood from the blood bank at University Hospital, Ann Arbor, Michigan, between 1 January, 1952, and 31 December, 1953. The information on 10,368 individual records taken from the blood bank included only the ABO type of the persons receiving transfusions. In order to get data on the age, sex, and disease of these patients the diagnostic records of the hospital had to be searched. Approximately 200,000 diagnostic records were examined in order to obtain these data. The following information was then available for each transfused patient: age, sex, race, county or state of residence, services to which admitted, each specific diagnosis, kinds of therapy, status upon discharge (ranging from improved to dead), x-ray therapy if any, death, and results of a Kahn test. The total size of the sample was reduced to 7747 after duplicate entries and individuals listed as "black" had been removed. "Black" individuals, so listed by admissions clerks, comprised less than 10% of the sample. The numbers reported in the analysis discussed below were obtained with the use of an IBM counting sorter.

First, we specified the age distribution with the four ABO blood groups. The cards were sorted into nine age groups, 0-1 year, 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71 and older. Then, a chi-square test for homogeneity by age

was run. The distribution by age is shown in table 1. The chi-square value, 42.4051 with 24 degrees of freedom, is significant ( $.01 < p < .02$ ), implying differences with respect to age in the distribution of the ABO groups within this

TABLE 1  
*ABO blood groups and sex ratios distributed among nine age groups*

AGE GROUPS		O	A	B	AB	TOTALS
0 - 1	Males	115	109	27	10	261
	Females	67	55	14	5	141
	Sex ratio	1.716	1.982	1.928	2.000	1.901
1 - 10	Males	141	153	32	23	349
	Females	100	122	26	13	261
	Sex ratio	1.410	1.254	1.231	1.769	1.416
11 - 20	Males	135	130	35	14	314
	Females	117	113	29	20	279
	Sex ratio	1.154	1.150	1.207	0.700	1.125
21 - 30	Males	290	124	36	16	466
	Females	235	251	66	25	577
	Sex ratio	1.234	0.494	0.545	0.640	0.728
31 - 40	Males	179	179	45	19	422
	Females	265	247	59	15	586
	Sex ratio	0.675	0.725	0.763	1.276	0.857
41 - 50	Males	204	220	64	20	508
	Females	262	243	75	27	607
	Sex ratio	0.779	0.905	0.853	0.741	0.819
51 - 60	Males	281	280	62	22	645
	Females	190	202	51	29	472
	Sex ratio	1.479	1.386	1.216	0.759	1.210
61 - 70	Males	313	278	74	27	692
	Females	195	179	36	22	432
	Sex ratio	1.605	1.553	2.055	1.227	1.610
71 -	Males	225	196	53	16	490
	Females	98	109	28	10	245
	Sex ratio	2.296	1.798	1.893	1.600	1.897
TOTALS	Males	1883	1669	428	167	4147
	Females	1529	1521	384	166	3600
	Sex ratio	1.231	1.097	1.115	1.006	1.152

sample. (We accept  $p \leq .02$  as the minimum acceptable level of significance.) The largest differences appear to be in the 21-30 age class, which shows there is an elevation of the frequency of group O, and a decrease in group A. Thus, there is an indication that group A decreases with advancing age and that this is at the expense of group O; a regression analysis of blood groups A and O on age was run. The results of this regression analysis are listed in table 2. However, the regression of group A on the age groups 1-10 through 61-70 does not reach an acceptable level of significance and there is no evidence that group O is significantly correlated with age.

TABLE 2

*Regression analysis*

SOURCE	S. S.	D. F.	M. S.	F
A on Age Groups 1-10 to 61-70				
Regression	9.0262	1	9.0262	4.8971
Residual	9.2154	5	1.8430	
Total	18.2416	6		
$.05 < p < .10$				
O on Age Groups 1-10 to 61-70				
Regression	.0305	1	.0305	.0057
Residual	26.5897	5	5.3179	
Total	26.6202	6		
$p > .10$				

The chi-square for homogeneity of age groups versus blood groups was partitioned in order to discover the cells which contributed most to the total. Table 3 is a summary of the division of the total chi-square into three groups of three partitions. This analysis implies that the crucial comparison is between blood groups O and A.

A test of sex and age versus the four blood groups was performed in order to pin-point the group which contributes most to the significance values. The sex ratios, male to female, for each age and blood group are included in table 1. It is interesting that the sex ratios decrease in the middle age groups. Table 4 summarizes the series of chi-



TABLE 3

*Blood groups versus age groups (Partitioned)*

PARTITION	CHI-SQUARE	D. F.	PROBABILITY
O : A	24.6269	8	$p < .01$
O + A : B	6.8805	8	$.50 < p < .70$
O + A + B : AB	10.7908	8	$.20 < p < .30$
SUM	42.2982	24	$.01 < p < .02$
O : B	10.3444	8	$.20 < p < .30$
O + B : AB	13.8983	8	$.05 < p < .10$
O + B + AB : A	18.1192	8	$.01 < p < .02$
SUM	42.3619	24	$.01 < p < .02$
A : B	6.1967	8	$.50 < p < .70$
A + B : AB	8.5777	8	$.30 < p < .50$
A + B + AB : O	27.1636	8	$.02 < p < .05$
SUM	41.9380	24	$.02 < p < .05$

TABLE 4

*Age and sex versus blood groups (Test of Homogeneity)*

AGE GROUPS	CHI-SQUARE	D. F.	PROBABILITY
0-1	.4474	3	$.90 < p < .95$
1-10	1.1994	3	$.80 < p < .70$
11-20	2.1979	3	$.50 < p < .70$
21-30	48.2987	3	$p < .01$
31-40	3.2760	3	$.30 < p < .50$
41-50	1.4964	3	$.50 < p < .70$
51-60	5.5820	3	$.10 < p < .20$
61-70	2.4836	3	$.30 < p < .50$
71-	8.9083	3	$.05 < p < .02$
Sum	73.8897	27	$p < .01$
0-20	3.8446	9	$.90 < p < .95$
21-50	53.0712	9	$p < .01$
51-	16.9739	9	$.02 < p < .05$
Sum	73.8897	27	
Total	7.3992	3	
Heterogeneity	66.4805	24	$p < .01$

Heterogeneity chi-square without 21-30 age group

Sum	25.5909	24	
Total	1.3208	3	
Heterogeneity	24.2701	21	$.20 < p < .30$

square values calculated to test the distribution of age and sex against blood groups. The heterogeneity chi-square value, 66.4905 with 24 degrees of freedom, is significant ( $p < .01$ ). This implies sex and age differences in the blood group distribution in the sample. However, one of the age groups, 21-30, has a very large chi-square. Collecting chi-squares into three age groups demonstrates that the 51 and older group also produces a value which suggests significance but falls below our accepted level. Removing the 21-30 age group reduces the total heterogeneity chi-square and it is no longer significant (table 4).

Statistical tests which we have applied to the data thus far suggest a scrutiny of age group 21-30 may reveal associations between blood group O and disease. A large variety of different diagnoses were grouped into very general classes in order to make tests of the distribution possible. The class gastro-intestinal disorders includes all diagnoses which involve the gastro-intestinal tract as the major site of disease. All traumatic diagnoses and ailments or surgery due to malformations of the gastro-intestinal tract were not included in this class. Each diagnostic class was constructed using similar principles.

Males and females of the age group 21-30 differ from each other significantly with respect to the frequencies of the ABO blood groups. In order to determine whether they differ significantly this way for each diagnostic class, a chi-square was run for each of the three classes with enough members to permit such a test: gastro-intestinal disorders, genito-urinary tract disorders, and elective surgery. The chi-square, 9.9320 with 3 degrees of freedom for the distribution of blood groups between the sexes in the class gastro-intestinal tract disorders is significant ( $.01 < p < .02$ ). The other values are not. In this diagnostic class it is clearly the ratio of blood group O to blood group A that differs from expectations. If this ratio is found among all age groups, then it is legitimate to infer that a selective mechanism may be responsible.

The absolute numbers of gastro-intestinal disorders in each age group classified by sex and blood group are listed in table 5. A test of the ratio of blood group O to blood group A in each sex in each group was performed. The class 71 years and older is too small for a meaningful test of significance. The significant results are summarized in table 6. The chi-square values imply that the ratio of blood group O to group A is significantly higher in males than females between the ages of 21 and 60. It is unfortunate that we cannot break down the diagnostic classes into groups precisely defined by the site of lesion, rupture, ulcer, tumor, etc. The

TABLE 5  
*Blood groups in gastro-intestinal disorders classified by age and sex*

AGE GROUPS	SEX	O	A	B	AB	TOTALS
0-1	Males	25	29	6	2	62
	Females	14	13	9	3	39
1-10	Males	10	13	2	3	28
	Females	5	6	1	1	13
11-20	Males	18	9	4	1	32
	Females	14	7	1	1	23
21-30	Males	102	29	6	3	140
	Females	18	14	6	1	39
31-40	Males	50	14	6	2	72
	Females	18	20	5	3	46
41-50	Males	105	32	7	3	157
	Females	36	38	5	5	84
51-60	Males	97	50	10	4	161
	Females	29	38	5	3	75
61-70	Males	62	30	9	4	105
	Females	16	13	3	3	35
71-	Males	35	20	2	2	59
	Females	6	5	1	1	13
Totals	Males	504	226	52	24	816
	Females	156	154	36	21	367

TABLE 6

*Blood groups in gastro-intestinal disorders*  
 Test of sex ratio classified by groups O and A

AGE GROUPS	CHI-SQUARE	D. F.	PROBABILITY
0-1	0.222	1	$.80 < p < .90$
1-10	.0118	1	$.90 < p < .95$
11-20	.0000	1	
21-30	6.1852	1	$.01 < p < .02$
31-40	10.5771	1	$p < .01$
41-50	16.8808	1	$p < .01$
51-60	9.7971	1	$p < .01$
61-70	1.9854	1	$.10 < p < .20$

TABLE 7

*Women transfused because of pregnancy related disorders*

AGE GROUPS	O	A	B	AB	TOTALS
11-20	8	12	2	0	22
21-30	62	89	26	10	187
31-40	27	48	11	7	93
41-50	3	7	2	2	14
Totals	100	156	41	19	316

Chi-square (transfused pregnant women vs.  
 all other transfused women) = 14.8669, 1 D. F.  
 $p < .01$

information was not available for this. Yet we suspect that males suffering from ulcers and experiencing hemorrhagic episodes may account for many of the individuals in this general category. If this is so, the trend, discussed by Aird *et al.* ('54), Westlund and Heisto ('55), and Clarke *et al.* ('56), for males of group O to be more susceptible to peptic ulceration is borne out. However, these data cannot be used directly to support this view.

The deviations in the pattern of the sex ratios suggest it might be well to investigate the distributions of blood groups among women in this sample who required transfusions because of disorders associated with pregnancy. The absolute numbers of women in this class in age groups 11-20, 21-30, 31-40, and 41-50 are listed in table 7. It can be shown,

with a chi-square test of ages against blood groups and blood groups against ages, that the trend found in women of age group 21-30 is present in the other age groups. Precisely, the distribution of ages against blood groups and blood groups against ages is not significantly heterogeneous for the four classes considered. The frequency of group O among all these women suffering from pregnancy associated difficulties is 31.64%, which is below the frequency of group O women in the total sample. These women can be classified into two groups, those possessing an antigen capable of stimulating an antibody reponse and those who do not. Of those requiring transfusions because of pregnancy, 68.36% are in the former class. A comparison between all other women requiring transfusions and the women in the category pregnancy disorders was made. A chi-square test of the difference between these two classes is summarized in table 7. The two values are significant. This implies that the divisions between group O women on the one hand and group A, B, and AB women on the other, with respect to pregnancy disorders requiring transfusions, is related to the illnesses included in that class. Despite the suggestion that there is a difference in attack rates for males and females for various diseases, the sex ratio differences in our sample are puzzling. The highest sex ratio in this sample (table 1) is in the first two age groups in individuals of groups O and A. Further study of the sex ratio at birth related to the loss of certain ABO groups due to maternal-fetal serological incompatibility is suggested.

The sample reported here has certain special characteristics; therefore, it would be unwise to generalize from it too widely. It represents a sub-group of sick people; those requiring blood transfusions. The patients were referred to the hospital from the entire state of Michigan, though analysis of the residence composition of the sample indicated that less than 5% came from outside the Lower Peninsula. In spite of special features, the distribution of the ABO types is heterogeneous within the sample and there is evi-



dence that it is heterogeneous because of factors related to disease and, hence, to natural selection.

A control population should be sampled for comparisons. Controls for data on admissions to a referral hospital are extremely difficult to obtain. Blood donors to hospital blood banks are unsatisfactory for a number of reasons. The age and sex distributions are not normal and such a sample is selected to match the recipients in blood type.

Hervey, Diamond and Watson ('51) published the results of a nationwide Red Cross blood bank drive conducted during the years 1948 and 1949. The information they

TABLE 8

*ABO distribution of hospital patients compared with Detroit area donors*

SOURCE		O	A	B	AB	TOTALS
Patients	Number	3412	3190	812	333	7747
	Percent	44.04	41.18	10.48	4.30	100.00
Donors	Number	2396	2350	683	299	5728
	Percent	41.83	41.03	11.92	5.22	100.00
Chi-square = 15.8742, 3 D. F. p < .01						

provide about the composition of the regional samples indicates they are more representative of the healthy population at large, at least with respect to age distribution, than are donors to hospital blood banks.

The figures for the Detroit area published in the above survey were used as a control for comparative purposes. The majority of individuals in this control group were males, persons in the industrial, clerical and professional classes of the white population. It seems reasonable to conclude this is a sample of healthy individuals from the same general population from which the sample of sick people came. The difference in frequency of the blood groups is significant and suggests that further investigation of the sick versus healthy classification of ABO frequencies is warranted. The results of this analysis are in table 8.

The comparison of the hospital sample with the healthy donor sample from the Detroit area raises a number of statistical questions since the differences in ABO frequencies between the two samples are significant. If the two samples represent the same general population, then the differences indicate that there is differential susceptibility to illness with respect to the ABO blood groups. It has been claimed that differences in ABO frequencies such as this are due to ethnic stratification of the populations or samples compared (Wiener, '43; '56). The unlikelihood of ethnic stratification with respect to the demonstrated associations between group O and peptic ulceration and group A and gastric carcinoma has been discussed by Clarke *et al.* ('56). It does not seem reasonable that the Detroit area donors and the University Hospital patients represent different ethnic stratifications of a sufficient magnitude to affect significantly the blood group frequencies. We cannot settle this point and thus must exercise caution in generalizing from the differences.

#### DISCUSSION

At present three associations between disease and the ABO blood groups-secretor-complex have been demonstrated. These are: peptic ulceration and blood group O and the secretor factor (Aird *et al.*, '54; Westlund and Heisto, '55; Clarke *et al.*, '56), gastric carcinoma and blood group A (Aird *et al.*, '54; K  ster *et al.*, '55; Buckwalter *et al.*, '56; Jennings *et al.*, '56; Billington, '56), and the rheumatic sequelae of streptococcus infections of the throat and secretion of ABO antigens in the saliva and gastric juice (Glyn *et al.*, '56).

The data reported in this study support but do not confirm the trends demonstrated by these investigators. While many of the patients included in the sample that were classified as having gastro-intestinal disorders certainly suffered from peptic ulceration, our classification system cannot give exact frequencies.

The fact that group A was significantly reduced in frequency in the class gastro-intestinal disorders is apparently

a direct consequence of the association of group O with peptic ulcers which, of course, is unexpected in the light of the association previously discovered with gastric carcinoma. This is probably due to the small number of cases of gastric carcinoma, since there were less than a hundred in our sample.

What explanation have we for the association between group O and gastro-intestinal disorders? We might expect such an association to be related to properties of the group specific substances themselves. If there are differences in the protection against disease and inflammation which the three substances afford, then it is not unexpected that group O is associated with increased morbidity. The ABO group specific substances are present in large volume and high titer in the gastro-intestinal tract, in the saliva, bile and gastric juice of about 80% of the individuals in European populations (Hartmann, '41; Kabat, '56) and they have recently been found on the surface of tissue cells (Coombs *et al.*, '56). Such individuals possess a dominant gene for the secretion of the substances in water soluble form (Schiff and Sasaki, '32). The A and B substances are well known (Pardee and Blaker, '51; Morgan, '56). The substance associated with the O gene has recently been demonstrated (Morgan and Watkins, '48) and its chemical composition has been determined (Kabat, '56). There are large differences in molecular weights among the three. The A and O substances have significantly lower weights than the B substance. If inflammation and cancer are related to the permeability of the cell wall, as Eyring and Dougherty ('55) suggest, then it is possible that the group specific substances are differentially related to mechanisms which protect the tissue cells of the gastro-intestinal tract. The heavier molecule, group specific substance B, is assumed to afford the greater protection against permeability. This suggestion, is, of course, speculative. It is, nonetheless, based on actual physicochemical differences in the tissues of the four ABO phenotypes.

Our data indicate that women of groups A, B, and AB suffer a morbid risk significantly greater than group O women. These two classes of women differ with respect to two things. Group O women possess an antigen that does not seem capable of stimulating an antibody response and two naturally occurring antibodies circulate in their serum. Group A, B, and AB women possess antigens capable of stimulating antibody production and have one or no naturally occurring antibody. Whether these differences are related to the increased morbid risk discovered for the former class is unknown. The secretor status of the woman and her fetus, whether she is part of a heterospecific mating, and whether she has been immunized against the RH antigens are other factors to be considered (Smith, '45; Levine, '57).

The analysis of the data in this report suggests that there are factors related to natural selection which affect the ABO phenotypes. The classification of the ABO frequencies by age and sex indicated differential susceptibility to certain morbid conditions; gastro-intestinal disease and pregnancy disorders. The significant differences in the ABO frequencies between healthy controls and the hospital sample imply that the physical fitness, age, and sex of individuals in samples taken for blood group surveys of populations are data which must be collected in the future.

#### SUMMARY

Examination of the age and sex composition of a sample of 7747 hospital patients receiving blood transfusions showed significant heterogeneity within the sample with respect to age and sex. Analysis of the significance showed that the ratio of blood group O to blood group A was significantly elevated in males suffering from gastro-intestinal disorders. The ratio of group O to groups A, B, and AB was significantly reduced among females suffering from pregnancy related disorders. Comparison with a sample of healthy individuals from the same general area showed significant dif-

ferences from the sample of transfused patients. The significance of the findings was discussed.

## LITERATURE CITED

- AIRD, I., H. H. BENTALI AND J. A. FRASER ROBERTS 1953 A relationship between cancer of the stomach and the ABO blood groups. *B. M. J.*, *1*: 799-801.
- BOYD, W. C. 1939 Blood groups. *Tabulae Biologiae*, Hague *17*: 113-240.
- 1953 The contributions of genetics to anthropology. In *Anthropology Today*, edited by Sol Tax. Chicago: University of Chicago Press.
- BILLINGTON, B. P. 1956 Gastric cancer. *Lancet*, *2*: 859-862.
- BRUES, A. M. 1952 Selection and polymorphism in the A-B-O blood groups. *Am. J. Phys. Anthropol.*, n. s., *12*: 559-597.
- BUCKWALTER, J. A., E. B. WOHLWEND, D. C. COLTER AND R. T. TIDRICK 1956 Natural selection associated with the ABO blood groups. *Science*, *123*: 840-841.
- CLARKE, C. A., J. W. EDWARDS, D. R. W. HADDOCK, A. W. HOWEL-EVANS AND R. B. MCCONNELL 1955 The relationship of the ABO blood groups to duodenal and gastric ulceration. *B. M. J.*, *2*: 643-646.
- COOMBS, R. R. A., D. BEDFORD AND L. M. ROUILLARD 1956 A and B blood group antigens on human epidermal cells. *Lancet*, *1*: 461-463.
- DIENST, A. 1905 Das Eklampsiegift. *Zentr. f. Gynäk.*, *29*: 353-364.
- EHRLICH, P., AND J. MORGENROTH 1900 Ueber Haemolysine. *Berl. Klin. Wochschr.*, *37*: 453-458.
- EYRING, H., AND T. DOUGHERTY 1955 Molecular mechanisms in inflammation and stress. I. *Amer. Scientist*, *43*: 457-467.
- GLASS, B. 1954 Genetic changes in human populations, especially those due to gene flow and genetic drift. *Advances in Genetics*, *6*: 96-139.
- GLYNN, A. A., L. E. GLYNN AND E. J. HOLBROW 1956 The secretor status of rheumatic-fever patients. *Lancet*, *2*: 759-762.
- HARTMANN, G. 1941 Group antigens in human organs. Copenhagen: Munksgaard.
- HERVEY, G. W., L. K. DIAMOND AND V. WATSON 1951 Geographic blood group variability in the United States. *J. A. M. A.*, *145*: 80-81.
- HIRSZFELD, I., AND H. HIRSZFELD 1919 Serological differences between the blood of different races. The result of researches on the Macedonian front. *Lancet*, *2*: 675-679.
- JENNINGS, D., R. H. BALME AND J. E. RICHARDSON 1956 Carcinoma of the stomach in relation to ABO blood-groups. *Lancet*, *2*: 11-12.
- KABAT, E. A. 1956 Blood group substances. New York: Academic Press.
- KØSTER, K. H., E. SINDRUP AND V. SEELE 1955 ABO blood-groups and gastric acidity. *Lancet*, *2*: 52-55.
- LEVINE, P. 1957 The influence of the ABO system on RH hemolytic disease. Read at 10th Annual Meeting, American Society of Human Genetics, Ann Arbor, Michigan.



- LIEPMANN, W. 1905 Zur Dienst'schen Eklampsietheorie. *Zentr. f. Gynäk.*, 29: 481-486.
- MANUILA, A. 1956 Distribution of A-B-O genes in eastern Europe. *Am. J. Phys. Anthropol.*, n. s., 14: 577-588.
- MORGAN, W. T. J. 1956 Blood group substances. In *Polysaccharides in Biology*, ed. by G. F. Springer, New York: Josiah Macy.
- MORGAN, W. T. J., AND W. M. WATKINS 1948 The detection of a product of the blood group O gene and the relationship of the so-called O substance to the agglutinogens A and B. *Brit. J. Exptl. Pathol.*, 29: 159-173.
- PARDEE, A. B., AND R. H. BLAKER 1951 Size and shape of blood-group A substance. *Proc. Soc. Exptl. Biol. Med.*, 73: 589-590.
- SCHIFF, F., AND H. SASAKI 1932 Der ausscheidungstypus, ein auf serologischen wege nachweisbares Mendelndes merkmal. *Klin. Wochschr.*, 34: 1426-1429.
- SMITH, G. H. 1945 Iso-agglutinin titres in heterospecific pregnancy. *J. Pathol. Bacteriol.*, 5: 223-228.
- VERZAR, M. F. 1922 Isohaemagglutination in anthropology. *Inst. Inter. d'Anthrop.*, 3: 419-426.
- WESTLUND, K., AND H. HEISTÖ 1955 Blood groups in relation to peptic ulceration. *B. M. J.*, 1: 847.
- WIENER, A. S. 1943 Blood groups and Transfusion. Springfield, Illinois: Charles C Thomas.
- 1956 Blood groups and disease. *Lancet*, 2: 1308.

# A BLOOD GROUP GENETICAL SURVEY IN EASTERN AND CENTRAL POLYNESIANS <sup>1</sup>

R. T. SIMMONS <sup>2</sup> AND J. J. GRAYDON <sup>3</sup>

*Commonwealth Serum Laboratories, Melbourne, Australia*

In a recent paper Simmons, Graydon, Semple and Fry ('55) tabulated the available blood group genetic data for Polynesians. The A-B-O gene frequencies had been known for most Polynesian peoples, but data for other blood group systems had only recently become available for Maoris of New Zealand, Cook Islanders and natives of Kapingamarangi a Polynesian people living in Micronesia. The conclusions reached after a study of the available data were:

"....that there is a close blood genetic relationship between American Indians and Polynesians, and that no similar relationship is evident when Polynesians are compared with Melanesians, Micronesians, and Indonesians, except mainly in adjacent areas of direct contact".

Data was lacking at that time relating to Central and Eastern Polynesia, areas in which air transport is lacking, and thus the collection of blood samples has been almost impossible to arrange. Thor Heyerdahl's Norwegian Archaeological Expedition to Easter Island and the East Pacific

<sup>1</sup> The authors acknowledge with gratitude a grant from the Wenner-Gren Foundation for Anthropological Research, Inc., which, in this instance, was used to defray air-freight charges.

<sup>2</sup> Research Associate, University of California, Los Angeles; Consultant, Commonwealth Serum Laboratories, Melbourne.

<sup>3</sup> Senior Consultant, Commonwealth Serum Laboratories, Melbourne.

in '55-'56, in a ship equipped with refrigerators offered an excellent opportunity to obtain blood samples from selected Polynesians. The samples were collected by the physician to the expedition Dr. Emil Gjessing who encountered considerable difficulty in locating Polynesians of unmixed blood, and in some cases getting blood samples donated.

Estimated, on census population figures for the islands sampled were:

Easter Island (Pascua) 842, Mangareva 500, Tubuai 1100, Rapaiti 278, Raivavae 770, Nukuhiva 806 and Hivaoa 884.

#### MATERIALS AND METHODS

The samples were collected between February and August 1956, into sterile glucose-citrate solution, stored on the ship at about 5°C., and subsequently sent to Melbourne by air-freight in ice-packed flasks. The first lot of blood samples collected from Easter Islanders were sent to us by courtesy of Dr. L. Sandoval of Santiago, Chile. Subsequent lots were despatched from Panama or Tahiti, and travelled to Melbourne either across the Pacific or via Amsterdam. The flasks were re-iced at various stopping places, and as a result, the samples reached us in excellent condition.

At Easter Island unmixed Polynesians were selected by Father Sebastian Englert who has studied their genealogy for many years. On other islands advice on selection was received from the local chief, native elders, school teachers, nurses or others who had studied the natives. The percentage of natives with unmixed blood on the various islands was low, Chinese admixture was most frequent with the exception of Easter Island. It is considered that in another generation it will be difficult to find any unmixed Polynesians in these islands. The methods employed for collecting and testing the samples have been described again in detail by Simmons, Graydon, Semple and Taylor ('51).

## RESULTS AND DISCUSSION

The results are given for all the islands visited although the numbers of individuals sampled are small. The numbers within an island group have been pooled, so that gene frequencies could be ascertained. Although these gene frequencies have been calculated from small numbers, it is our experience that they do convey the general gene frequency pattern within an island, or island group. The results obtained for the A-B-O groups and calculated gene frequencies are given in table 1, the M-N types, S distribution and gene frequencies in table 2, the Rh types and gene frequencies in table 3, and a summary of 11 other tests on the Polynesians are given in table 4.

*A-B-O groups.* In the A-B-O frequencies it will be noticed that group B was not found in 138 selected individuals, which confirms earlier observations that B is lacking in Polynesians of unmixed blood. Two earlier surveys had shown the *A* frequency for Easter Islanders as .423 and .472, while the present survey confirms the high *A* with a frequency of .46. A similarly high *A* frequency of .48 apparently prevails on Mangareva considerably west of Easter Island, although in an earlier survey *A* was .357. There appears to be some evidence of a gradient in *A* from east to west, however, the *A* frequencies throughout Polynesia are still higher than in Melanesia, Micronesia and Indonesia. No earlier frequencies have been seen by us for either the Tubuai or Marquesas Islands. All the samples of group A were of subgroup A<sub>1</sub>.

*The M-N-S types.* The *m* and *n* frequencies for Easter Islanders *m* .33 and *n* .67 differ from those of the peoples of Mangareva, the Tubuai and Marquesas Islands, and those found in earlier surveys in Cook Islanders and Maoris of New Zealand. The *m* frequency .33 was unexpectedly low. The Polynesian area differs from Melanesia and Micronesia in having *m* generally slightly in excess of .5. This elevated *m* has been associated as one of a series of possible links with American Indians, who possess the highest *m* values

known. The blood genetic evidence for a possible association between Polynesians and American Indians has recently been discussed by Simmons et al. ('55) and by Simmons ('56.) The S positive percentage is 13 compared with 12.2% in Maoris (N.Z.), and 18% in Cook Islanders. S appears to be more frequently associated with N than with M as was observed with Cook Islanders and Maoris, and also with other Pacific peoples. (Simmons, Graydon and Semple ['53]; Simmons, Graydon, Semple and Swindler, '56.)

*The Rh types.* Two Rh genes  $R^1$  and  $R^2$  are sufficient to account for the Rh phenotypes found in Easter Island, Mangareva and the Marquesas Islands. In the Tubuai Islands three genes  $R^1$ ,  $R^2$  and  $R^0$  are regarded as present. A very high  $R^2$  gene frequency is present in Easter Island, Manga-

TABLE 1  
*A-B-O blood groups and gene frequencies in Polynesians*

POPULATION	NO. TESTED	BLOOD GROUPS		GENE FREQUENCIES	
		O	A <sub>1</sub>	A	O
Eastern Polynesia					
Easter Island	51	15	36	.46	.54
Tuamotu Archipelago					
Mangareva	22	7	15	.48	.52
Tubuai Islands					
Tubuai	12	6	6	} .28	} .72
Rapaïti	17	7	10		
Raivavae	6	5	1		
Marquesas Islands					
Nukuhiva	24	11	13	} .32	} .68
Hivaoa	6	3	3		
Totals	138	54	84	.374	.626
		39.1%	60.9%		

reva and the Tubuai Islands, with the highest  $R^2$  frequency at Easter Island of .66. This frequency is possibly the highest  $R^2$  frequency recorded to date, and is similar to that of American Indians in British Columbia reported by Chown and Lewis (Mourant '54). The Rh gene frequencies for 138 Polynesians in the present survey are very similar to those



POPULATION	NO. TESTED	M-N TYPES			GENE FREQUENCIES		PROPORTION OF SAMPLES S-POSITIVE	DISTRIBUTION OF S-POSITIVE CELLS		
		M	MN	N	m	n		M	MN	N
Easter Island	51	5 9.8%	24 47.1%	22 43.1%	.33	.67	8/51	2/5	2/24	4/22
Mangareva	22	4	14	4	.50	.50	3/22	0/4	3/14	0/4
Tubuai	12	3	4	5			0/12	0/3	0/4	0/5
Rapaïti	17	8	6	3	.51	.49	3/17	0/8	3/6	0/3
Raivavae	6	1	2	3			0/6	0/1	0/2	0/3
Nukuhiva	24	4	13	7	.47	.53	4/24	0/4	1/13	3/7
Hivaaoa	6	2	3	1			0/6	0/2	0/3	0/1
Totals	138	27 19.6%	66 47.8%	45 32.6%	.435	.565	18/138 13.0%	2/27 7.4%	9/66 13.6%	7/45 15.5%

Approximate chromosomal frequencies calculated from the figures in the present survey are as follows:—

$$ms = .412; \quad mS = .023; \quad ns = .520; \quad nS = .045$$

TABLE 3

Rh types and gene frequencies

POPULATION	NO. TESTED	RH TYPES					GENE FREQUENCIES		
		Rh <sub>1</sub> Rh <sub>1</sub>	Rh <sub>1</sub> Rh <sub>0</sub>	Rh <sub>2</sub>	Rh <sub>1</sub> Rh <sub>2</sub>	Rh <sub>2</sub> Rh <sub>3</sub>	R <sup>1</sup>	R <sup>2</sup>	R <sup>0</sup>
Easter Island	51	9	0	25	17		.34	.66	....
Mangareva	22	3	0	6	13		.43	.57	....
Tubuai	12	2	1	0	9				
Rapaïti	17	1	0	5	11	24	.47	.51	.02
Raivavae	6	1	0	1	4				
Nukuhiva	24	11	0	2	11	15	.62	.38	....
Hivaaoa	6	0	0	2	4				
Totals	138	27 19.6%	1 .7%	41 29.7%	69 50.0%		.449	.543	.007



found for 180 Maoris of New Zealand by Simmons et al. ('51) and in 267 Cook Islanders by Simmons et al. ('55).

	$R^1$	$R^2$	$R^0$
Present survey	.449	.543	.007
Maoris	.465	.486	.027
Cook Islanders	.516	.459	.025

In spite of differences in observed physical characters it would seem that the above peoples are of basically the same stock, for the influences which have modified individual groups, have not changed to any extent the general Rh gene frequency pattern.

In Rh typing the blood samples three examples of  $Rh_0(D^n)$  variants were found. Two "high-grade" variants which were presumably homozygous were found in the Easter Island samples, and they have been included with those of type  $Rh_1 Rh_1$  in the table. One "low-grade"  $Rh_0(D^n)$  variant was found in the Tubuai samples, and it also was presumably homozygous. This sample has been included amongst the  $Rh_1 Rh_1$  samples in the table, it being classed as a "low-grade" variant by critical indirect Coombs tests. The classification of the sample was difficult, because on all preliminary anti-globulin tests it could have been recorded with justification as  $rh'rh'$ . It must be regarded as a border-line example.

*Other observations on Polynesians.* A summary of eleven other tests is presented in table 4. No example of  $rh^w(C^w)$  was found. The P positive percentage was 39.1, slightly lower than in Cook Islanders and Maoris, and this also applies to the  $Le(a+)$  percentage of 14.5. The Duffy ( $Fy^a$ ) percentage was 74.6 compared with Maoris 71.7% and Cook Islanders 92.1%. No examples of the Kell (K), Lutheran ( $Lu^a$ ), Batty (By), Henshaw (He), and Diego ( $Di^a$ ) antigens were found. No evidence of the sickle-cell trait was detected. In tests with phenyl thiocarbamide 92.1% were recorded as

tasters. The percentage is of the same high order as previously found in Polynesians. Data relative to the blood antigens Lu<sup>a</sup>, By, He and Di<sup>a</sup> and to the sickle-cell trait have not previously been recorded for Polynesians. All tests for the various blood group antigens were made by the authors' slide technique, with the exception of tests for Fy<sup>a</sup>, By and Di<sup>a</sup> which were made by the anti-globulin method.

A summary of tests for the Diego antigen in Polynesians, Australian aborigines (Central Australia, and Cape York), Papuans and natives of New Britain (Simmons, '57) shows that no example of the Diego antigen has been found to date in these people. Other investigators have shown the presence of the Diego antigen from 2% to over 50% in the blood of six South American Indian groups, in peoples of mixed blood in Venezuela, in Brazilian Indians, North American Indians (Chippewa) and in Chinese and Japanese resident in Canada and Venezuela. (Layrisse and Arends, '56; Lewis, Ayukawa, Chown and Levine '56.) It has been suggested that the Diego blood antigen is an Asiatic or Mongoloid characteristic rather than Indian, because of its presence in Chinese and Japanese blood. The present Diego survey in Polynesians was carried out to ascertain if possible evidence of a Mongoloid or American Indian component carrying the Diego antigen could be detected in Polynesians. Although the numbers of Pacific peoples tested to date is small, it can be said that no evidence has yet been found of a Diego-positive racial component common to natives of the Australasian area particularly Central and Eastern Polynesia, and to American Indians and Mongoloids, both of whom possess such a component.

Since writing the above, a report by Lewis, Chown and Kaita ('56) shows that the Diego antigen has been found in a second northern Indian tribe the Crees of northern Manitoba, that it is absent in a few Negroes tested, and that it is also absent in 156 Eskimos from the Eastern Canadian arctic which includes Hudson Bay, Baffinland and Labrador.

Thus we have the Diego antigen apparently absent in Eskimos and Polynesians, and present in widely varying degree (2% to over 50%) in American Indians and Mongoloids resident in Canada and Venezuela. The Diego antigen may prove of even greater anthropological importance than has been recently suggested.

#### ACKNOWLEDGMENTS

The authors are grateful to Mr. Thor Heyerdahl, leader of the Norwegian Archaeological Expedition to Easter Island and the East Pacific, and to Dr. Emil Gjessing for obtaining blood samples from selected Polynesians. We express our gratitude to Dr. Luis Sandoval of the University of Chile, Santiago, and to the respective Royal Norwegian Consuls at Panama and Tahiti for organizing the efficient transport of the samples. Messrs. C. Fernie & Co. of Christobal, Panama, were most helpful at all times.

The anti-Lutheran and anti-Henshaw testing sera were kindly supplied by Dr. A. E. Mourant of London several years ago. The anti-Diego serum was most generously sent to us by Dr. M. Layrisse of Caracas, Venezuela, specially for this investigation.

#### SUMMARY

The results of a blood genetical survey on 138 selected Polynesians from Eastern and Central Polynesia are reported. The blood groups determined were A<sub>1</sub>-A<sub>2</sub>-B-O, M-N-S, Rh, P, Le<sup>a</sup>, Fy<sup>a</sup>, K, Lu<sup>a</sup>, By, He and Di<sup>a</sup>. Tests for the sickle-cell trait and P. T. C. taste tests were also carried out. The results obtained are comparable with those previously reported for Maoris of New Zealand and Cook Islanders, and in a number of characters are comparable with some South American Indian tribes.

No such similarity is evident when comparisons are made with Melanesians, Micronesians and Indonesians.



All the data reported for Eastern and Central Polynesians are new except some of the A-B-O frequencies. Tests not previously carried out on any Polynesian people are those for the Lutheran, Batty, Henshaw and Diego blood groups, and the sickle-cell trait. Few Polynesians of unmixed blood remain in the islands sampled.

## LITERATURE CITED

- LAYRISSE, M., AND T. ARENDS 1956 The Diego blood factor in Chinese and Japanese. *Nature*, 177: 1083-1084.
- LEWIS, M., H. AYUKAWA, B. CHOWN AND P. LEVINE 1956 The blood group antigen Diego in North American Indians and Japanese. *Nature*, 177: 1084.
- LEWIS, M., B. CHOWN AND H. KAITA 1956 Further observations on the blood factor Di<sup>a</sup>. *Nature*, 178: 1125.
- MOURANT, A. E. 1954 The distribution of the human blood groups. Blackwell Scientific Publications, Oxford, pp. 1-438.
- SIMMONS, R. T. 1956 A report on blood group genetical surveys in Eastern Asia, Indonesia, Melanesia, Micronesia, Polynesia and Australia in the study of Man. *Anthrops*, 51: 500-512.
- 1957 The Diego (Di<sup>a</sup>) blood group: Tests in some Pacific Peoples. *Nature*, 179: 970-971.
- SIMMONS, R. T., J. J. GRAYDON AND N. M. SEMPLE 1953 A further blood genetical survey in Micronesia: Palauans, Trukese and Kapingas. *Med. J. Australia*, 2: 589-596.
- SIMMONS, R. T., J. J. GRAYDON, N. M. SEMPLE AND E. I. FRY 1955 A blood group genetical survey in Cook Islanders, Polynesia, and comparisons with American Indians. *Am. J. Phys. Anthropol.*, 13: 667-690.
- SIMMONS, R. T., J. J. GRAYDON, N. M. SEMPLE AND D. R. SWINDLER 1956 A blood group genetical survey in West Nakanai, New Britain. *Am. J. Phys. Anthropol.*, 14: 275-286.
- SIMMONS, R. T., J. J. GRAYDON, N. M. SEMPLE AND C. N. D. TAYLOR 1951 Blood, taste and secretion: A genetical survey in Maoris. *Med. J. Australia*, 1: 425-431.

# POSTNATAL GROWTH OF THE FRONTAL AND PARIETAL BONES IN WHITE MALES <sup>1</sup>

RICHARD W. YOUNG <sup>2</sup>

*The Fels Research Institute, Yellow Springs, Ohio*

THREE FIGURES

## INTRODUCTION

Growth in certain major dimensions of the human head, such as circumference and width, has been described in many anthropometric studies. Similarly, the study of head growth in man has been advanced by investigations with other animals which have yielded much information about processes of cranial ossification. Little is known, however, concerning postnatal age changes in individual osseous components of the human cranium. In this regard the longitudinal x-ray series is useful, for it enables the investigator to fractionate the growing skull into a number of parts—although sites of growth within these units cannot be precisely determined.

The present study uses this approach to record changes with age in median sagittal size and shape of the frontal and parietal bones in white males.

## MATERIAL AND METHODS

The sample consisted of two series, one of which was longitudinal, the other cross-sectional. The first group was made up of 20 boys from the Fels growth study for whom lateral skull x-rays were available at specified intervals from one

<sup>1</sup> Presented in part at the 25th annual meeting of the American Association of Physical Anthropologists, Chicago, April, 1956.

<sup>2</sup> Present address: Department of Anatomy, College of Physicians and Surgeons, Columbia University. (Predoctoral Fellow [MF-6409] National Institutes of Health, Public Health Service.)

month to 16 years. The second group comprised 50 adult males between 20 and 62 years (mean age 37 years) of whom one lateral skull plate each was obtained.

The adult subgroup was drawn largely from the Fels study. Three Fels employees and 5 Antioch College faculty members were included. All 70 individuals were white, native-born residents of southwestern Ohio; most were of northwest European ancestry.

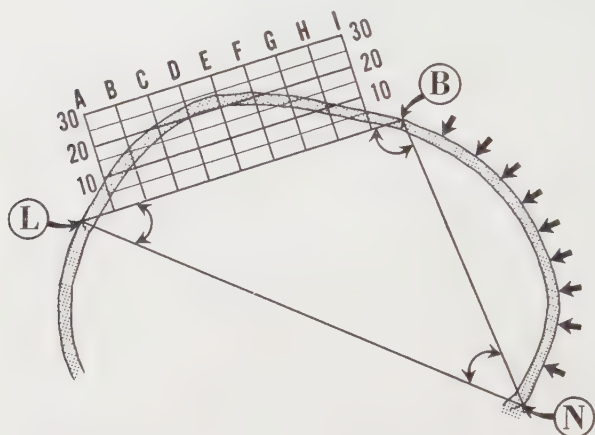


Fig. 1 Diagram of a lateral skull x-ray, illustrating the dimensions measured. L, lambda; B, bregma; N, nasion. The grid used for the shape index (cf. Young, '56) is shown superimposed on the parietal bone. The base line coincides with the lambda-bregma chord. Heights of the nine equally-spaced perpendiculars (A-I) are expressed as percentages of the base line. Curved arrows indicate the angles of the lambda-bregma-nasion triangle. Nine arrows along the frontal bone designate the sites at which bone thickness was measured.

In the longitudinal material, x-rays were examined, where available, at 1, 3, 6, and 9 months, and 1, 2, 3, 4, 6, 8, 10, 12, 14, and 16 years.

The measurements taken were as follows (see fig. 1):

- (1) *Frontal arc*: The distance from nasion to bregma along the outer table of the bone.
- (2) *Parietal arc*: The distance from bregma to lambda along the outer table of the bone.

(3) *Frontal chord*: The straight-line distance from nasion to bregma.

(4) *Parietal chord*: The straight-line distance from bregma to lambda.

(5) *Lambda, bregma and nasion angles*: Angles of the lambda-bregma-nasion triangle.

(6) *Frontal and parietal shape*: This was measured by the shape index (Young, '56). Nine equally-spaced perpendiculars were erected from the chord of each bone to its outer table. These perpendiculars were then expressed as percentages of the chord.

(7) *Frontal and parietal thickness*: Bone thickness was measured, where x-ray clarity permitted, at the intersections of shape index perpendiculars with the outer table of each bone. Average values are reported here, each mean being based on at least 5 of the 9 possible thicknesses. No measurements were made in the glabella region if there was encroachment of the frontal sinus.

Arcs were obtained by means of a steel tape, calibrated in millimeters. A metric ruler was used to measure chords, and was read to the nearest 0.5 mm. Angles were determined with a protractor, and recorded to the nearest 0.5 degree. Vernier calipers with tips ground to a point were used to measure bone thickness to the nearest 0.1 mm.

#### RESULTS

Summarizing values according to age were computed for all variables. These statistics for frontal and parietal arcs are given in table 1. It is evident that there is rapid deceleration in growth of the parietal in this dimension during the early years, with little or no change after the age of 4. Examination of individual curves revealed that in 10 of 20 cases there were no increments between 4 and 16 years.

Averages for the frontal arc revealed a similar but not identical pattern. After the early period of rapidly decelerating growth, there is little anteroposterior expansion. There is

TABLE 1

*Frontal and parietal arcs: summarizing values,<sup>1</sup> by age*

AGE	FRONTAL ARC				Range	PARIETAL ARC				
	N	Mean	S. E.	S. D.		N	Mean	S. E.	S. D.	Range
1 month	13	81.2	1.8	6.2	72-90	15	107.1	2.7	10.0	95-135
3 month	13	93.3	1.7	5.9	80-106	13	120.2	3.0	10.3	104-149
6 month	15	103.6	1.7	6.2	91-115	15	127.2	2.6	9.6	117-159
9 month	15	107.5	1.2	4.4	98-113	15	131.2	2.8	10.3	122-165
1 year	18	114.8	1.4	5.8	100-125	18	135.8	2.3	9.4	124-170
2 year	19	127.6	1.7	7.1	110-137	19	143.0	2.5	10.4	129-179
3 year	20	128.4	1.5	6.7	113-140	19	143.8	2.0	8.5	127-179
4 year	19	130.1	1.6	6.8	114-142	19	146.1	2.4	10.0	134-182
6 year	20	130.9	1.8	7.7	114-147	20	146.0	2.5	11.0	129-177
8 year	18	131.2	1.6	6.5	118-142	18	146.5	2.9	11.9	129-179
10 year	20	133.5	1.8	8.0	118-149	20	147.9	2.6	11.4	130-179
12 year	20	134.6	1.8	7.7	119-149	20	147.9	2.6	11.2	130-177
14 year	20	134.9	1.8	8.0	118-149	20	148.3	2.6	11.1	129-178
16 year	12	135.4	1.9	6.2	121-145	12	146.6	3.9	13.0	129-179
Adult	50	140.5	1.0	7.1	125-158	50	145.6	1.4	9.8	121-177

<sup>1</sup> Uncorrected for x-ray enlargement (4.4-5.0%).



however, more of an indication of continued growth through 16 years.

The tabulated means for the frontal and parietal chords (table 2) give a comparable picture. Here too there is a suggestion that parietal growth may cease before frontal expansion has been completed.

Average values at successive ages are given in table 3 for the mean thicknesses of the frontal and parietal bones in the median sagittal plane. There is continued thickening of both bones at a diminishing rate throughout the period studied, although deceleration is less rapid than in sagittal growth.

Table 4 presents a summary, by age, of the angular measurements. The angle at bregma increases quite regularly from one month to adulthood. The average lambda angle, on the other hand, is stable throughout the growth period. Thus the angle at nasion diminishes in direct relation to the expansion of the bregma angle.

Figure 2 expresses certain of these trends graphically.

Mean data for frontal and parietal shape is given in tables 5 and 6. The frontal bone generally becomes increasingly more arched until the third year. This was the case in all 20 subjects. A similar trend is evident for the parietal, although maximum curvature is reached somewhat earlier in this bone. Inspection of individual curves substantiated this conclusion. After these early periods of increasing convexity, both bones become progressively flattened. Sixteen-year shape is only slightly more rounded than the average adult bone morphology.

Summarizing statistics were computed for age increments in arcs, average thickness and the bregma angle. These similarly revealed a rapid early deceleration of sagittal expansion, a more gradual deceleration of thickening and of increase in the angle at bregma.

The allometry of the frontal and parietal bones was examined by plotting the mean arc lengths at successive ages on a

TABLE 2

*Frontal and parietal chords: summarizing values,<sup>1</sup> by age*

AGE	FRONTAL CHORD				PARIETAL CHORD					
	N	Mean	S. E.	S. D.	Range	N	Mean	S. E.	S. D.	Range
1 month	13	73.0	1.3	4.4	67-80	15	94.3	1.7	6.4	84-109
3 month	13	81.9	1.6	5.5	74-92	13	104.3	1.7	5.8	94-119
6 month	15	89.3	1.0	3.9	82-96	15	111.1	1.6	6.0	104-130
9 month	15	93.4	1.0	3.8	86-99	15	114.7	1.7	6.3	107-135
1 year	18	99.6	1.0	4.3	90-109	18	119.6	1.4	5.6	112-139
2 year	19	109.2	1.1	4.8	97-115	19	127.8	1.6	6.6	118-146
3 year	20	110.0	1.0	4.3	101-117	19	128.1	1.5	6.2	117-147
4 year	19	111.5	1.1	4.6	99-118	19	129.8	1.5	6.4	122-150
6 year	20	113.2	1.1	4.8	103-123	20	130.5	1.7	7.5	119-146
8 year	18	114.2	1.1	4.5	104-120	18	130.4	1.9	7.9	119-147
10 year	20	116.3	1.2	5.3	104-125	20	131.9	1.8	7.8	119-149
12 year	20	117.9	1.4	6.0	105-128	20	132.2	1.8	7.8	120-148
14 year	20	118.8	1.3	5.6	105-129	20	132.4	1.7	7.6	119-149
16 year	12	120.0	1.6	5.3	107-126	12	130.6	2.4	8.1	120-149
Adult	50	122.1	0.8	5.4	107-121	50	130.1	1.1	7.9	123-150

<sup>1</sup> Uncorrected for x-ray enlargement (4.4-5.0%).

TABLE 3

*Frontal and parietal thickness: <sup>1</sup> summarizing values,<sup>2</sup> by age*

AGE	FRONTAL THICKNESS				PARIETAL THICKNESS					
	N	Mean	S. E.	S. D.	Range	N	Mean	S. E.	S. D.	Range
1 month	13	1.1	0.1	0.3	0.6-1.4	13	0.5	0.1	0.2	0.3-0.9
3 month	13	1.4	0.1	0.2	1.1-1.7	13	0.9	0.1	0.2	0.6-1.4
6 month	14	1.6	0.1	0.4	1.1-2.3	15	1.3	0.1	0.3	1.0-1.8
9 month	15	2.0	0.1	0.4	1.2-2.5	15	1.9	0.1	0.4	1.3-2.6
1 year	17	2.3	0.1	0.4	1.7-3.3	17	2.2	0.1	0.5	1.5-3.2
2 year	19	3.1	0.1	0.5	2.1-3.9	19	3.0	0.1	0.5	2.0-4.0
3 year	19	3.5	0.1	0.5	2.8-4.1	18	3.4	0.1	0.5	2.4-4.8
4 year	19	3.6	0.1	0.5	2.9-4.7	19	3.8	0.1	0.5	3.0-5.1
6 year	20	4.1	0.1	0.4	3.4-4.8	20	4.2	0.1	0.4	3.6-5.5
8 year	17	4.2	0.2	0.6	3.3-5.2	17	4.6	0.1	0.5	3.6-5.5
10 year	18	4.4	0.1	0.5	3.6-5.5	18	4.8	0.1	0.5	4.1-5.6
12 year	18	4.6	0.2	0.6	3.8-6.1	17	5.0	0.1	0.5	4.3-6.0
14 year	18	4.9	0.2	0.7	3.7-6.7	15	5.3	0.1	0.5	4.5-6.4
16 year	7	5.2	0.3	0.7	4.2-6.0	6	5.7	0.2	0.4	5.2-6.3
Adult	37	5.8	0.1	0.8	4.5-7.6	35	6.1	0.1	0.7	4.6-7.7

<sup>1</sup> Mean of 5-9 thicknesses along the median sagittal arc.<sup>2</sup> Uncorrected for x-ray enlargement (4.4-5.0%).

**TABLE 4**  
*Lambda-bregma-nasion triangle; summarizing values, by age*

AGE	BREGMA ANGLE				NASION ANGLE				LAMBDA ANGLE				
	N	Mean	S. E.	S. D.	Range	Mean	S. E.	S. D.	Range	Mean	S. E.	S. D.	Range
1 month	13	87.9	1.2	4.2	78.5-96.5	52.8	1.2	4.0	46.5-64.0	39.3	0.6	2.0	37.0-44.0
3 month	13	90.1	1.6	5.4	79.5-99.5	51.4	1.3	4.5	45.0-63.0	38.5	0.7	2.4	35.5-43.5
6 month	15	90.1	1.3	4.8	79.5-99.0	51.2	1.1	4.2	45.0-63.0	38.7	0.5	2.0	36.0-42.0
9 month	15	90.3	1.3	4.9	79.5-99.5	50.6	1.3	4.8	44.0-63.5	39.0	0.6	2.2	36.0-44.0
1 year	18	92.4	1.2	5.1	80.0-99.5	48.4	1.1	4.7	42.0-63.0	39.1	0.5	1.9	36.5-44.0
2 year	19	93.6	1.0	4.1	81.5-99.0	47.3	1.0	4.3	42.0-62.5	39.1	0.3	1.1	36.0-41.0
3 year	19	93.5	1.0	4.2	79.5-99.0	47.2	1.0	4.3	42.0-62.5	39.3	0.3	1.4	37.0-42.0
4 year	19	93.7	1.0	4.3	80.0-99.0	46.9	1.1	4.7	40.5-63.5	39.4	0.4	1.6	36.5-42.0
6 year	20	94.5	1.0	4.4	82.0-100.5	46.2	1.0	4.3	40.0-60.5	39.3	0.3	1.4	37.0-42.0
8 year	18	95.3	1.1	4.5	82.5-101.5	45.6	1.2	4.8	39.5-60.0	39.1	0.3	1.2	37.5-41.0
10 year	20	96.1	1.1	4.6	83.0-102.0	45.2	1.1	4.7	39.0-60.0	38.8	0.3	1.1	37.0-41.0
12 year	20	96.9	1.0	4.3	85.0-103.5	44.3	1.0	4.5	38.5-58.0	38.8	0.3	1.2	36.5-41.0
14 year	20	97.8	1.0	4.4	86.0-105.0	43.6	1.0	4.4	38.0-57.0	38.6	0.3	1.1	37.0-40.0
16 year	12	98.9	1.4	4.6	87.0-105.0	42.5	1.5	5.0	37.0-56.0	38.6	0.2	0.8	37.0-40.0
Adult	50	99.9	0.5	3.4	90.5-107.0	41.5	0.5	3.2	32.0-52.5	38.6	0.4	2.5	32.5-44.0

double logarithmic scale. With allowance for sampling artifacts, the points fell along a straight line after one month, indicating simple allometry. The value of  $k$  (the average ratio between two specific growth rates) was 0.6. Stability of  $k$

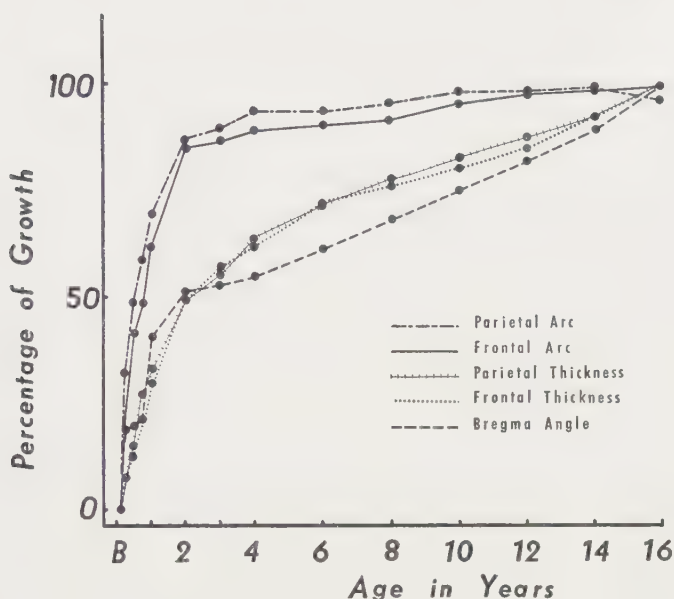


Fig. 2 Percentage of growth completed (1 month—16 years). The minimum (1 month) average subtracted from the maximum average gives the total growth in a dimension during the period studied. Intermediate averages are then expressed as percentages of this total (intermediate average—minimum average  $\div$  total growth  $\times 100$  = percentage of growth). This permits the comparison of growth changes, irrespective of size differences, in arcs, thickness and angulation.

was investigated by plotting the successive ratios against time (Richards and Kavanagh, '45). No consistent shift with age either side of the mean value was observed.

Moss, Noback and Robertson ('56) have presented frontal and parietal chord averages for prenatal material. These are plotted in figure 3 along with the Fels postnatal means for chord length. At about the third postnatal month an "inter-phase" appears, indicating that ectocranial frontal growth



TABLE 5

Frontal shape: summarizing values, by age<sup>1</sup>

AGE	N	NINE PERPENDICULARS (PERCENTAGE OF CHORD)																	
		A		B		C		D		E		F		G		H		I	
		Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.
1 month	13	8.0	1.6	13.3	1.9	17.2	2.4	20.7	2.3	22.7	1.6	23.2	1.4	21.5	1.4	17.1	1.6	9.8	1.4
3 month	13	9.1	1.5	14.8	2.0	19.3	2.3	22.8	2.0	24.4	2.0	24.7	1.9	22.8	1.9	17.7	2.1	10.2	1.5
6 month	15	9.5	1.1	15.5	1.5	20.2	1.6	23.6	1.6	25.2	1.3	25.7	1.8	24.0	1.8	19.0	1.7	11.2	1.2
9 month	14	9.8	1.2	16.2	1.9	20.7	1.9	23.6	1.8	25.0	1.8	25.5	2.0	23.8	1.8	18.6	1.8	10.5	1.4
1 year	18	9.6	0.7	16.4	1.3	20.9	1.4	23.7	1.8	25.0	1.8	25.3	2.3	23.6	1.8	18.3	1.8	11.0	1.1
2 year	19	9.2	0.9	16.3	1.4	21.0	1.8	24.1	1.8	25.6	1.8	26.1	2.0	24.7	2.1	19.6	2.2	12.0	1.4
3 year	20	9.1	0.9	16.1	1.2	21.2	1.6	24.3	1.8	25.7	1.9	25.8	2.4	24.5	2.1	19.8	2.0	12.4	1.3
4 year	19	9.1	0.7	16.0	1.1	20.9	1.4	24.0	1.7	25.5	2.1	25.8	2.3	24.5	2.2	19.5	2.1	12.4	1.3
6 year	20	8.7	0.9	15.6	1.1	20.5	1.4	23.7	1.9	24.9	2.0	25.1	2.3	23.5	2.3	18.7	2.2	12.4	1.9
8 year	18	8.4	1.0	14.9	1.1	19.9	1.4	22.8	1.6	24.2	1.7	24.5	2.3	22.4	2.3	17.5	2.2	11.1	1.4
10 year	20	8.4	1.0	15.1	1.5	20.1	1.6	22.9	1.9	24.4	2.2	24.5	2.4	22.5	2.5	17.5	2.3	11.4	1.6
12 year	20	8.1	1.4	14.7	1.2	19.5	1.6	22.5	2.0	23.8	2.2	23.8	2.5	21.5	2.7	16.5	2.3	10.8	1.3
14 year	20	7.9	0.8	14.4	1.1	19.0	1.6	22.0	1.9	23.3	2.1	23.3	2.4	21.0	2.4	15.9	2.3	10.8	1.3
16 year	12	7.7	1.0	14.2	1.1	18.7	1.0	21.3	1.2	22.2	1.9	22.0	1.9	19.3	2.3	14.8	1.7	10.2	1.4
Adult	50	8.1	1.2	14.5	1.7	19.1	1.9	21.7	2.0	22.8	2.1	22.1	2.3	19.3	2.5	14.7	1.9	11.8	1.6

<sup>1</sup>A decreasing mean value indicates a decrease in the elevation above the chord of the corresponding bone segment.

TABLE 6

Parietal shape: summarizing values, by age<sup>1</sup>

AGE	N	NINE PERPENDICULARS (PERCENTAGE OF CHORD)																	
		A		B		C		D		E		F		G		H		I	
		Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.	Mean	s. d.
1 month	15	10.4	1.0	17.0	2.0	21.4	2.2	23.5	2.4	23.8	2.6	22.5	2.9	20.2	2.8	16.1	2.7	9.9	1.6
3 month	13	10.0	1.5	17.1	2.5	21.5	2.7	23.7	2.9	23.9	2.9	23.0	3.0	21.0	2.7	16.5	2.6	9.9	1.6
6 month	15	10.5	1.4	17.7	2.2	22.0	2.3	24.4	2.5	24.7	2.4	23.5	2.6	21.2	2.4	16.4	2.1	9.7	1.4
9 month	15	10.7	1.5	18.1	2.1	22.2	2.1	24.5	2.4	25.1	2.3	23.8	2.3	21.1	2.1	16.0	2.0	9.2	1.3
1 year	18	10.2	1.3	17.3	1.8	21.2	2.1	23.8	2.1	24.3	2.0	23.1	2.3	19.9	2.4	14.9	2.0	8.5	1.4
2 year	19	9.5	1.3	16.4	1.8	20.9	1.9	23.1	2.0	23.6	2.4	22.4	2.5	19.1	2.4	13.9	2.2	7.7	1.6
3 year	19	9.6	1.7	16.2	1.9	20.7	1.9	23.1	2.0	23.4	1.9	22.2	2.3	18.9	2.2	13.7	2.1	7.6	1.4
4 year	19	9.4	1.4	16.4	1.8	20.8	1.4	23.3	1.9	23.5	1.9	22.1	2.4	19.1	2.1	13.8	2.2	7.5	1.4
6 year	20	9.5	1.5	16.1	1.9	20.6	2.1	23.0	2.0	23.2	2.0	21.9	2.2	18.7	2.3	13.7	2.0	7.3	1.5
8 year	18	9.3	1.2	15.8	2.0	20.4	2.0	22.9	2.0	23.0	2.0	21.8	2.3	18.6	2.4	13.7	2.3	7.3	1.5
10 year	20	9.2	1.3	15.8	1.9	20.2	1.9	22.3	2.0	22.9	1.9	21.7	2.3	18.6	2.3	13.6	1.9	7.3	1.4
12 year	20	8.9	1.4	15.8	2.0	20.2	2.0	22.4	1.9	23.0	2.1	21.7	2.3	18.6	2.4	13.7	2.2	7.3	1.5
14 year	20	9.1	1.3	15.6	1.7	19.8	1.9	22.5	1.9	22.7	1.8	21.6	2.2	18.7	2.2	13.7	2.0	7.4	1.5
16 year	12	8.4	1.3	15.2	1.9	19.5	2.1	21.9	2.1	22.4	2.3	21.2	2.6	18.3	2.7	13.4	2.4	7.2	1.5
Adult	50	8.0	1.4	14.9	1.9	19.2	2.0	21.9	2.0	22.3	2.1	21.0	2.0	17.9	1.8	13.3	1.5	7.3	1.0

<sup>1</sup> A decreasing mean value indicates a decrease in the elevation above the chord of the corresponding bone segment.

may occur at an increased rate relative to the parietal after that age.  $k = 1.1$  (prenatal) and  $0.7$  (postnatal).

How accurately do the cross-sectional statistics represent individual specific growth ratios? Individual values for  $k$  range from  $0.2$  to  $0.8$  for arcs, and from  $0.3$  to  $0.8$  for chords. Average  $k$  values, derived from the individual  $k$ 's are identical with those obtained from the slopes of the group data.

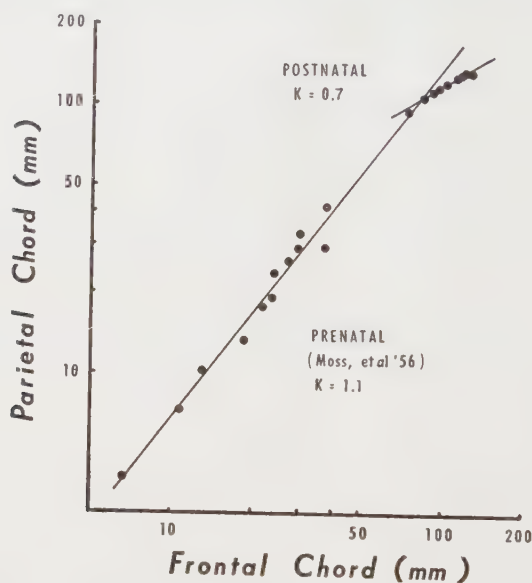


Fig. 3 Allometric relationship between frontal and parietal chords, prenatal and postnatal. A change in slope ( $k$ ) is evident postnatally in this double logarithmic plot.

The correlation between arc lengths of the two bones was computed at each age (table 7). A low, negative relationship from 6 months through adulthood was observed. In general, the correlations are not statistically significant, and it may be concluded that it is useless to attempt to predict the length of one arc in an age-constant series when only the length of the other is known.

The correlation between average thicknesses of both bones was also calculated at all ages. All values were positive (table

7), and 6 of 14 were significant at the 1 percent level. For a given age, then, it is possible to roughly estimate the thickness of one bone if the thickness of the other is known.<sup>3</sup>

TABLE 7  
*Correlation of cranial dimensions, by age<sup>1</sup>*

AGE	FRONTAL ARC: PARIETAL ARC	FRONTAL THICKNESS: PARIETAL THICKNESS
1 month	0.27	0.09
3 month	0.02	0.37
6 month	-0.29	0.59 <sup>6</sup>
9 month	-0.34	0.81 <sup>5</sup>
1 year	-0.19	0.74 <sup>5</sup>
2 year	-0.33	0.61 <sup>5</sup>
3 year	-0.42 <sup>4</sup>	0.53 <sup>4</sup>
4 year	-0.33	0.57 <sup>5</sup>
6 year	-0.34	0.35
8 year	-0.43 <sup>4</sup>	0.41
10 year	-0.33	0.43 <sup>4</sup>
12 year	-0.35	0.12
14 year	-0.24	0.13
16 year	-0.51 <sup>4</sup>	...
Mean r <sup>3</sup>	-0.28	0.47
Adult	-0.14	0.66 <sup>5</sup>
Adult <sup>2</sup>	-0.09	0.66

<sup>1</sup> N = 10 or more.

<sup>2</sup> Normalized distribution (McCall's T-scores: Johnson, '49; Lacey, '56). The correlations are apparently not significantly altered by skewing.

<sup>3</sup> Fisher *z* transforms (Fisher, '48). Longitudinal sample only.

<sup>4</sup> 5% level of significance.

<sup>5</sup> 1% level of significance.

## DISCUSSION

The data presented show that median sagittal expansion of the frontal and parietal bones in white males is characterized by rapid postnatal deceleration and early cessation, a pattern which clearly reflects brain enlargement.

<sup>3</sup> Using the average thickness (7.0 mm) of the Swanscombe parietal, along the sagittal suture (Morant, '38), the value 6.8 mm may be predicted for thickness of the frontal bone (based on the Fels adult males correlation). The chances are 2 to 1 that the true value falls between 6.2 and 7.4 mm. (These figures are within the  $\pm 2$  S. D. range of the Fels adult sample).

It appeared that sagittal ectocranial growth of the frontal bone is more rapid after birth than before, *relative to the parietals*, and, furthermore, is more prolonged. This has been reported in a long-snouted form, the rat (Massler and Schour, '51; Moss, '54; Baer, '54). However, since man is not long-snouted, these findings may not be directly comparable.

Three factors seem to be important.

(1) The first of these is remodelling at the coronal suture, as described by Bateman ('54) in the mouse, and Brash ('34) in the pig and in man. Due to differential growth of inner and outer tables at the bone edges, the coronal suture may "migrate" backwards ectocranially, yielding an apparent predominance of frontal growth. This would be more apparent postnatally, as bone thickness becomes appreciable.

(2) The second factor is the development of a frontal sinus. The recorded differences in growth gradient are less evident in chords than in arcs. This indicates that the frontal growth advantage may in part be related to the pneumatization of the frontal sinus. The associated separation of inner and outer tables at glabella may increase arc length without altering the chord.

(3) The third factor is the adjustment of the anterior frontal bone to growth of the facial skeleton. Bony ectocranial apposition resulting in a late, localized extension at glabella (with or without sinus development) has been reported in man (Davenport, '43; Brodie, '53). This accompanies continued longitudinal growth of the upper facial structure (Björk, '55).

These three phenomena appear to account for the postnatal predominance of frontal growth relative to the parietal.

Support for the finding that during postnatal growth the nasion angle decreases, the bregma angle increases and the lambda angle is stable is found in the work of Björk ('55) and especially Bergerhoff ('53).

The possibility of slow angular movement at the membranous coronal suture may be considered in interpreting these observations. There is marked sutural mobility at birth



(Moloy, '42), and probably later adjustments between bones at the sutures (Mijsberg, '32; Giblin and Alley, '44; Moss, '54). The angular changes herein reported, however, are more apt to be a reflection of factor (3) above: the response of the outer table of the frontal bone to growth of the facial skeleton.

Attention is thereby directed to the functional independence of inner and outer tables in vault bones (Klaauw, '46; Delattre and Fenart, '54; Simon, '55). The inner plate responds primarily to the underlying brain. The outer plate, altered in some regions by muscle attachments, manifests the formation of a frontal sinus at glabella and the expansion of the face at nasion. Apparently the frontal bone contributes to both the neural and facial skeletons (Klaauw, '46; Brodie, '53; Scott, '55; Mednick and Washburn, '56).

Changes with age in the thickness of adult crania have been studied in cross-sectional material by Anderson (1882), Todd ('24), Hartl and Burkhardt ('52) and Hartl and Luther ('53). All recorded a slight thickening. Macdonald ('54a, '54b) has described increases in cranial bone thickness in late prenatal material. A paper by Roche ('53) appears to be the only previous study of vault thickening in a postnatal subadult sample. At each age Roche's means for thickness at (1) vertex and (2) midway between nasion and bregma agree closely with the Fels averages for the parietal and frontal bones, respectively. Thus these two points seem to give an adequate picture of average bone thickness along the midline.

The increase in the radius of curvature of individual cranial bones during growth is one of the mechanisms by which the vault adjusts to the expansion of intracranial contents. In the Fels sample the parietal begins to flatten at about 9 months, the frontal some two years later. This decrease in curvature continues until final shape is attained.

The period of flattening was found to be preceded by a phase in which the bones actually become more arched along the midline. Previous indications of this development may be found in reports of age changes in the cephalic index (e.g., Davenport, '40; Abbie, '47; Ewing, '50; Barber and Hewitt,

'56). The infants studied experienced a rapid increase in the index until the age of 8 or 9 months, after which it began to drop. Abbie ('47) contends that the reversal does not occur in dolicocephalic groups. It is improbable that birth molding is involved, since its effects seldom last more than a few days or weeks (Moloy, '42; Henderson and Sherman, '46; Ortiz and Brodie, '49). The growth curve of the brain or its parts (Noback and Moss, '56) and of head circumference (Meredith, '46) seems to be regular during the period in question.

It has been suggested (cf. Ewing, '50) that the early increase in cephalic index is due to occipital molding imposed by the characteristic neonatal sleeping position. The reversal in trend is ascribed to the beginning assumption of upright posture. In the Fels sample the early curvature increase is measurable in both parietal *and* frontal bones, and is actually more persistent in the latter. Consequently, if localized pressure on the back of the head is indeed responsible for these changes, it evidently leads to compensatory adjustments in other regions of the cranial vault.

The mean, age-constant correlations between average thicknesses of the frontal and parietal bones showed that these dimensions are positively related. Apparently surface apposition and resorption are influenced by factors common to both bones. These may in part be of endocrine origin (Mortimer, '37; Mortimer, Levene and Rowe, '37; Burkhardt, '50).

Similar correlations between arc-lengths were statistically insignificant, suggesting a measure of autonomy in sagittal growth of these bones. This is supported by the finding of inter-individual differences in relative growth rates for the two components. Further confirmation is presented by the data of Pearson and Davin ('24) and Pearson and Woo ('35), whose studies of dried crania showed that dimensions of non-homologous bones are not correlated. Barnicot ('47) postulated a certain independence of growth pattern for vault bones on the basis of histological research. Moss ('54) called attention to the different times of ossification and maturation for individual bones. Similarly, Baer's ('54) work with vital

staining led him to conclude that "the centers of ossification may have an individual specificity in terms of growth potential." Apparently the individual (non-homologous) bones of the cranium grow somewhat independently.

Certain facts of cranial growth may be summarized in this light: Bone area increases by peripheral periosteal osteogenesis from the original ossification centers. Concomitantly, the bones are carried outward within the neurocranial capsule, which is expanding to accomodate the growing brain (Moss, '54). Eventually osteogenesis overcomes this continuing separation of the bones, and the margins of adjacent skull components approximate each other. The definitive form of each bone, then, depends upon the position of ossification centers (which may be influenced by the sites of dural attachment: Kokott, '33), the time of beginning osteogenesis, and the relative growth of marginal periosteal tissues.

On the other hand, the overall size and form of the vault (in thin-skulled animals) is primarily a reflection of the size and form of the brain. This is exemplified in human microcephaly, and in Moss's ('54) data, in which gross dimensions of the rat cranium were not altered by sutural excision, although changes in individual bone form occurred.

These principles lead to the prediction that sutural synostosis will be later, bone area greater, and overall vault size increased, when intracranial contents are larger than usual. This is seen to be the case in hydrocephalus.

It is suggested that in thin-skulled animals such as man brain development determines the gross dimensions of the cranial vault, while a number of other factors mediate the extent to which individual bones contribute to it. Among these are the location, time of appearance, and growth potential of ossification centers.

#### SUMMARY

1. Postnatal age changes in size and shape of the frontal and parietal bones were studied using lateral skull x-rays

obtained from a longitudinal sample of 20 boys and a cross-sectional sample of 50 men.

2. The major increments in chord and arc length of both bones are completed at an early age; bone thickening occurs somewhat more slowly.

3. In the lambda-bregma-nasion triangle, the bregma angle increases, the nasion angle decreases, and the lambda angle is stable.

4. Both bones become more arched during the early months, then reverse this trend, growing increasingly flatter thereafter.

5. Allometric analysis of frontal and parietal chords revealed an interphase shortly after birth.

6. The average thicknesses of both bones are positively correlated.

7. Arc-length correlations are statistically insignificant.

8. The determination of size and form of individual cranial components and of the vault as a whole was discussed.

#### ACKNOWLEDGEMENTS

The writer is grateful to Dr. Lester W. Sontag, Director of the Fels Research Institute, and Dr. Stanley M. Garn, Chairman of the Physical Growth Department, for giving him the opportunity to conduct this study. The cooperation of Mr. Paul Ebert, Fels Librarian, was particularly helpful. Jennifer Young patiently and accurately carried out a large part of the statistical computation.

#### LITERATURE CITED

- ABBIE, A. A. 1947 Headform and human evolution. *J. Anat.*, 81: 233—258.
- ANDERSON, R. J. 1882 Observations on the thickness of the human skull. *Dublin J. Med. Sci.*, 74: 270—280.
- BAER, M. J. 1954 Patterns of growth of the skull as revealed by vital staining. *Human Biology*, 26: 80—126.
- BARBER, C. R., AND D. HEWITT 1956 Growth of the skull in young children. Part II: Changes in head shape. *J. Neurol., Neurosurg., Psychiat.*, 19: 54—56.
- BARNICOTT, N. A. 1947 The supravital staining of osteoclasts with neutral-red. *Proc. Royal Soc., B*, 134: 467—485.

- BATEMAN, N. 1954 Bone growth: a study of the grey-lethal and microphthalmic mutants of the mouse. *J. Anat.*, *88*: 212-262.
- BERGERHOFF, W. 1953 Wachstum und Bauplan des Schädels im Röntgenbild. *Fortschr. Röntgenstr.* *79*: 745-760.
- BJÖRK, A., 1955 Cranial base development. *Am. J. Orthodont.*, *41*: 198-225.
- BRASH, J. C. 1934 Some problems on the growth and developmental mechanics of bone. *Edinburgh Med. J.*, *41*: 305-319, 363-387.
- BRODIE, A. G. 1953 Late growth changes in the human face. *Angle Orthodont.*, *23*: 146-157.
- BURKHARDT, L. 1950 Über Dichtemessungen am menschlichen Schädeldach als Beitrag zur Kenntnis von Umbauveränderungen und konstitutionellen Verschiedenheiten—unter Berücksichtigung der Hypophyse. *Verhand. Deutschen Gesellschaft für Path.*, *34*: 275-289.
- DAVENPORT, C. B. 1940 Postnatal growth of the head. *Proc. Am. Phil. Soc.*, *83*: 1-215.
- 1943 The development of the head. *Am. J. Orthodont. Oral Surg.*, *29*: 541-547.
- DELATRE, A., AND R. FENART 1954 Le crane acromégale, ses rapports avec la morphogenèse du crane. *Annales d'Endocrin.*, *15*: 684-693.
- EWING, J. F. 1950 Hyperbrachycephaly as influenced by cultural conditioning. *Peabody Mus. Papers*, *23*: 1-99.
- FISHER, R. A. 1948 Statistical methods for research workers. Oliver and Boyd, London.
- GIBLIN, N., AND A. ALLEY 1944 Studies in skull growth. Coronal suture fixation. *Anat. Rec.*, *88*: 143-153.
- HARTL, F., AND L. BURKHARDT 1952 Über Strukturumbau des Skelets, besonders des Schädeldachs und Schlüsselbeins, beim Erwachsenen und seine Beziehungen zur Hypophyse, nach Massgabe des spezifischen Gewichts und histologischen Befundes. *Virchows Archiv.*, *322*: 503-528.
- HARTL, F., AND J. LUTHER 1953 Vergleichende Messungen am Kopf und am knöchernen Schädel als Beitrag zur Konstitutionsbiometrie. *Z. menschl. Vererb. u. Konstitutionslehre*, *31*: 381-390.
- HENDERSON, S. G., AND L. S. SHERMAN 1946 The roentgen anatomy of the skull of the newborn infant. *Radiol.*, *46*: 107-118.
- JOHNSON, P. O. 1949 Statistical methods in research. Prentice-Hall, New York.
- KLAUW, C. J. VAN DER 1946 Cerebral skull and facial skull. A contribution to the knowledge of skull structure. *Arch. Neerl. d'Zool.*, *7*: 16-37.
- KOKOTT, W. 1933 Über den Bauplan des fötalen Hirnschädels. *Gegenbauers Morphol. Jahrb.*, *72*: 341-361.
- LACEY, J. I. 1956 The evaluation of automic responses: Toward a general solution. *Ann. N. Y. Acad. Sci.*, *67*: 123-164.
- MACDONALD, I. 1954a Hardness and growth of the foetal head. *J. Obs. Gyn.*, *61*: 253-258.
- 1954b Chemical analysis of human foetal skull bones. *Biochem. J.*, *57*: 437-439.



- MASSLER, M., AND I. SCHOUR 1951 The growth pattern of the cranial vault in the albino rat as measured by vital staining with alizarine red "S". *Anat. Rec.*, 110: 83-101.
- MEDNICK, L. W., AND S. L. WASHBURN 1956 The role of the sutures in the growth of the braincase of the infant pig. *Am. J. Phys. Anthropol.*, N. S., 14: 175-186.
- MEREDITH, H. V. 1946 Physical growth from birth to two years: II. Head circumference. *Child development*, 17: 1-61.
- MIJSBERG, W. A. 1932 Die Funktion der Nähte am wachsenden Schädel. *Zeit. f. Morph. u. Anthropol.*, 30: 535-551.
- MOLOY, H. C. 1942 Studies on head molding during labor. *Am. J. Obs. Gyn.*, 44: 762-782.
- MORANT, G. M. 1938 The form of the Swanscombe skull. *J. Roy. Anthropol. Inst.*, 68: 67-97.
- MORTIMER, H. 1937 Pituitary and associated hormone factors in cranial growth and differentiation in the white rat: a roentgenological study. *Radiol.*, 28: 5-39.
- MORTIMER, H., G. LEVENE AND A. W. ROWE 1937 Cranial dysplasias of pituitary origin. I. and II. *Radiol.*, 29: 135-157; 279-295.
- MOSS, M. L. 1954 Growth of the calvaria in the rat. *Am. J. Anat.*, 94: 333-362.
- MOSS, M. L., C. R. NOBACK AND G. G. ROBERTSON 1956 Growth of certain human fetal cranial bones. *Am. J. Anat.*, 98: 191-204.
- NOBACK, C. R., AND M. L. MOSS 1956 Differential growth of the human brain. *J. Comp. Neurol.*, 105: 539-552.
- ORTIZ, M. H., AND A. G. BRODIE 1949 On the growth of the human head from birth to the third month of life. *Anat. Rec.*, 103: 311-333.
- PEARSON, K., AND A. G. DAVIN 1924 On the biometric constants of the human skull. *Biometrika*, 16: 328-363.
- PEARSON, K. AND T. L. WOO 1935 Further investigations of the morphometric characters of the individual bones of the human skull. *Biometrika*, 27: 424-465.
- RICHARDS, O. W., AND A. J. KAVANAGH 1945 The analysis of growing form. In W. E. Le Gros Clark and P. B. Medawar. *Essays on Growth and Form*. Clarendon Press, Oxford, 188-230.
- ROCHE, A. F. 1953 Increase in cranial thickness during growth. *Human Biology*, 25: 81-92.
- SCOTT, J. H. 1955 Craniofacial regions. *Dental Pract.*, 5: 208-214.
- SIMON, E. 1955 Vordere und mittlere Schädelgrube bei Laboratoriums- und Haussäugetieren. II Mitteilung. *Acta Anat.*, 23: 206-241.
- TODD, T. W. 1924 Thickness of the male white cranium. *Anat. Rec.*, 27: 245-256.
- YOUNG, R. W. 1956 The measurement of cranial shape. *Am. J. Phys. Anthropol.*, N. S., 14: 59-72.

# THE UNRELIABILITY OF BLOOD TYPING AGED BONE

FREDERICK P. THIEME AND CHARLOTTE M. OTTEN  
*University of Michigan*

## INTRODUCTION

When Boyd and Boyd ('33) and Candela ('36) first demonstrated the possibility of the ABO blood typing of aged human bone and tissues, anthropologists were quick to realize the potential value of such data for historical studies of human populations. It was, in fact, this appealing potential which encouraged the profession to have greater faith in the reliability of such tests than was actually warranted.

Boyd and Boyd ('39), using 14 known autopsy samples up to five years old, achieved typing results which they called "encouraging but not as conclusive as would be wished for unknown material" (p. 424). When Candela ('40) successfully typed a portion of their material, doubts were somewhat relieved. But an element of uncertainty remains. In the first place, the growing literature of serological research leads to a conception of the blood group ABO polysaccharide-polypeptide antigens as substances immensely stable under some conditions, but contrastingly fragile under others.

In the second place, the method employed in bone typing is not sufficiently exact or specific to meet the requirements of the problem. The several shortcomings of this method will be discussed below.

When the Laboratory of Physical Anthropology was first set up at the University of Michigan under sponsorship of the Wenner-Gren Foundation, we secured over 40 bone samples from individuals of known blood type at autopsy. These have been tested after aging by means of the standard inhibition

test. Blood stains of known type were similarly tested after aging and drying. The role of bacterial enzymes in the disintegration of blood group antigens was next investigated. Thus our work reported here falls into three sections: Bone Typing, Stain Typing, and the Action of Bacterial Enzymes on Blood Group Antigens.

#### METHODS, TECHNIQUES AND RESULTS

The test procedure used in the typing of aged bone is a crucial factor in determining the reliability of the results. For this reason it is necessary to describe the test and its limitations before the results of our studies can be evaluated.

The inhibition test depends upon the reduction in titer of known antisera by the inhibiting action of specific antigens. The reduction in titer is, in turn, detected by the differential agglutination of appropriate red cells added to the antisera. However, such titer reduction may occur for reasons other than by combination with specific antigens. Deterioration of the antisera without regard to the presence of antigen may occur during the test period and may proceed at unequal rates. In spite of refrigeration and the addition of bactericides such may well be the case with polluted material. The notorious instability of antibodies makes both differential and absolute deterioration by contaminants possible in the absence of specific antigens over the period in which the antibody inhibition progresses. That such bacterial products may reduce antibody titer without reference to antigens present will be demonstrated below.

Another source of test error is from non-specific absorption which apparently is due to the inorganic and physical properties of the material tested. Particle size is probably the most important factor and we have shown (Thieme, et al., '56) that such serologically inert materials as charcoal, kaoline and benzonite can cause very significant antibody titer reduction. The great variability in the nature of decomposing bone, as we shall see, can make for differences in absorption so that it may progress at a different rate and to a different degree,

say, in the case of bone samples which are originally pasty, friable or fairly compact before being ground for testing. Using agglutinins of identical titer, bone of extremely fine particle size will presumably lower the titer significantly more than larger ones without regard to the blood type.

Other hazards of testing lie in the ubiquitous distribution of substances closely resembling blood group antigens in the animal and plant world which can act as contaminants and give false inhibition reactions. Salazar Mallen ('51), for instance reports that the soil surrounding specimens from Monte Alban gave A type reactions similar to that of the skeletal material tested. Some bacterial polysaccharide components themselves closely resemble blood group antigens and very specific tests would be necessary to detect such contaminants. Another matter of concern is the observation that powdered bone loses its antigenic reactivity shortly after fine grinding, unless sealed in vacuum containers. The consistency and porosity of bone itself apparently has a bearing on antigen retention. Furthermore, cancellous bone and spongy bone are probably different in this respect as well as in their original antigen content.

### *I. Bone typing*

Over 40 autopsy samples, mostly lumbar vertebrae, were buried in stone jars in sandy soil, and aged from 2 to 3 years. Blood type was determined from heart blood recovered from each individual at autopsy, and secretor status from a sample of bile, according to a modification of Boyd's secretor test for saliva. The accuracy of our bile test was checked by procuring both saliva and bile samples from cholecystectomy patients at the University of Michigan hospital. Comparisons showed the secretor test on bile to be completely reliable.

Nineteen individual bone specimens were typed by the standard inhibition technique. All the B and AB specimens were used and the seven O and eight A were selected from the total of these types. The selection was made of those which were

most completely decomposed and free from residual fat. Many of the other specimens contained a large amount of fat which makes typing practically impossible with standard test methods. Both immune antisera and alpha and beta isoagglutinins were used, of titers of 1:8, 1:16 and 1:32 respectively. Thus each ground bone specimen was subjected to twelve individual testings, involving three dilutions each of the four antisera. Pooled AB sera was the diluent used in order to maintain constant density and thus better equalize physical factors, including those relating to the phenomenon of non-specific absorption. Hemolysis caused some difficulty in reading the tests, but was partially overcome by increasing surface tension by raising salt concentration, adjustment of pH, or by using higher-titered antisera (1:128) which gave faster differential readings. The latter step is admittedly a risky procedure, and advisable only in combination with more traditional techniques.

The typing results are recorded in table 1. Since by this an O cannot be distinguished from a total loss of antigen, the A, B and AB most reliably indicate the degree of success in antigen recovery and specificity. Of the 12 specimens not type O, only 4 tested as expected giving an error rate of 75 per cent. We do not know whether the errors were due to the destruction of the A and/or B antigens, or whether they have been transformed to O. Some more sensitive technique will have to be employed in such cases to indicate the presence of O antigen since so called "anti-O" sera made from absorbed cattle sera, *Ulex europeus* extract, or chicken antisera appears to be unsatisfactory for the purpose of indicating O antigen in old bone using this test method.

The appearance of the vertebrae upon exhumation presented great variation, ranging from a chalky, gray, friable consistency throughout with visible mold mycelia and little odor, to a dark brown pasty rancid-smelling interior. We also found intermediate shades of brown and tan, and intermediate putrifactive odors and textures. We found that the dark brown ran-



TABLE 1  
*ABO blood typing results on variously treated and aged samples of bones and blood*<sup>1</sup>

SAMPLE	KNOWN TYPE	NUMBER TESTED	TYPING RESULTS <sup>2</sup>				PERCENT WRONG
			O	A	B	AB	
1. Human bone aged 2 years, buried in sandy soil	O	7	6	(1)	—	—	47%
	A	8	(5)	3	—	—	
	B	3	(2)	—	1	—	
	AB	1	(1)	—	—	—	
1A. Whole blood stains on filter paper	O	6	6	—	—	—	0%
	A	6	6	6	—	—	
	B	4	—	—	4	—	
	AB	3	—	—	—	3	
b. Samples 3 weeks in open tubes, then dried on paper	O	6	4	(2)	—	—	37%
	A	6	(2)	4	—	—	
	B	4	(1)	—	3	—	
	AB	3	(1)	(1)	—	1	
c. Samples 2 months in open tubes, then dried on paper	O	6	3	(3)	—	—	53%
	A	6	(3)	2	—	(1)	
	B	4	(1)	—	3	—	
	AB	3	(2)	(1)	—	—	
d. Samples with 0.5 gms. polluted soil added, aged in open tubes 2 weeks, then dried on paper	O	3	—	—	(2)	(1)	100%
	A	3	(1)	—	(1)	(1)	
	B	3	(3)	—	—	—	

Note: 1. Numbers in parentheses are tests giving readings different from known type.

2. No inhibition of anti-A or anti-B is recorded as O. Probably little or no specific blood group substance of any type remains.

cid types of decomposition presented the greatest problems in typing, and least often gave satisfactory results.

These varying characteristics must be ascribed to the action of different organisms possibly already present in the tissue at the time of burial and/or in the soil. The samples were buried at different times over the period of a year and the soil used was not identical although it came from the same location. The unreliability of the results seems to implicate bacterial action.

## *II. Stain typing*

Stains made from fresh blood of known type and dried upon filter paper have continued to give completely accurate readings after aging at room temperature for nine months. However, blood allowed to putrify in open tubes at room temperature three weeks before drying gave 37% error. When kept eight weeks before drying, the error was 53% (see table 1). These results are in substantial agreement with the work of Gettler and Kramer ('36) and the unreliability seems clearly to increase as bacterial action is more prolonged.

To obtain maximum decomposition a gram of manure-laden soil was added to each of three tubes of fresh O and A and B type blood which was then used to make stains after two weeks of putrification. Not one of these tested accurately. In examining our results, one might be led to speculate whether a transformation of one type of antigen to another had taken place. Unfortunately the inhibition test cannot now be relied upon to test for the presence of O antigens due to the absence of a specific human anti-O. As apparent transformations are mainly from A and/or B to O, their testing must be done more exactly and specifically than is possible with the inhibition procedure.

## *III. Action of bacterial enzymes on blood group antigens*

Workers for over two decades, including Stack and Morgan ('49) Schiff, ('35, '39) and Iseki and his colleagues, ('51, '52, '53, '55, '56) have shown that certain bacterial enzymes may

act to decompose not only the blood group antigens but the structurally-related pneumococcus carbohydrates as well. Over a dozen such organisms have been named to date, most of which may occur naturally in soil, fecal material or decaying animal or vegetable matter. They are, in general, at least facultative anaerobes, sacchrolytic in action, and thus ideal candidates to be held accountable under some conditions for the decomposition of antigens in aged skeletal material.

About half of these organisms have been found to attack the A antigen; one attacks B; the rest deteriorate various constellations of antigens, with some strains effecting a complete deterioration of all ABO (H) blood group substances. Iseki and his colleagues, in a recent series of articles ('51, '52, '53, '55, '56), have claimed not only antigenic deterioration, but transformation from one blood group into another. This work may be summarized as follows:

1. An enzyme which decomposes A, but not B or O (H) was obtained from *Clostridium tertium*.
2. A heat labile (5 minutes at 60° C.) enzyme decomposing O, but not A or B obtained from *Bacillus fulminans*.
3. An enzyme which decreases A substance, and increases O, in A secretor saliva and thus appears to transform A into O was obtained from *Clostridium tertium* (as in 1, above).
4. The enzyme of *Bacillus fulminans* decomposes T substance (probably Le<sup>a</sup>) found in ABO non-secretor saliva.
5. The changes in type are ascribed to separation of fucose from the group substance.
6. Using an enzyme produced by *Bacillus cereus*, B substance was transformed into O (H).

These studies conclude that specific group substances can be selectively destroyed by enzymatic action and that A and B can be transformed into O (H).

In repeating certain relevant aspects of former work, the enzyme of *Clostridia perfringens*, the soil organism most frequently associated with gas gangrene infections, was used in

testing. Culture filtrates of three other *Clostridia* species, *novyi*, *sporogenes*, and *septicum* were used as controls. The action of culture filtrates of the four species were studied in relation to commercial blood group antigens, antigens in secretor saliva, and erythrocytes. The destruction of A substance prepared from hog gastric mucin, and in human saliva after 24 hours exposure, was verified in the case of *perfringens*; there was no such effect from the control enzymes. Thus, we have verified that closely related enzymes may behave differently.

In all cases the bacterial filtrates from known strains were prepared from 24-hour cultures grown anaerobically in fluid thioglycollate medium (Difco), centrifuged at high speed, and run through a Seitz filter.

A, B and O secretor saliva as well as commercial A and B antigens prepared from hog gastric mucin were set up in dilutions of 1:10, 1:50, 1:100 and 1:200. A mixture of the bacterial enzyme-filtrate and neutral phosphate buffer were used in equal parts for diluent. Controls were prepared in two lots: without the addition of antigens, and without the enzyme, which was replaced by saline. After 24 hours, all samples were tested for the presence of antigen by means of the inhibition test. Commercial A antigen appeared entirely destroyed by *perfringens* enzyme, while B was unchanged. In the case of secretor saliva, there was either total destruction of A, or, in one case, an almost complete reduction of A except for a small amount which persisted to lower the titer of *Ulex* by one tube. There is also the possibility here of a partial transformation from A into O, as claimed for *Clostridium tertium* by Iseki. However, until a successful specific anti-O as against an anti-H indicator (such as *Ulex*) is developed, we cannot demonstrate conclusively the transformation of secretor antigens from one blood group into another.

A further complication is presented by the agglutinating behavior of erythrocytes exposed to dilute and buffered *perfringens* enzyme. Group A cells, upon exposure, demonstrate a panagglutination toward all antisera, especially strongly

affected by *Ulex* extract. Cells of all blood groups, in fact, react more strongly to *Ulex* after even a few hours of exposure to the enzyme, or perhaps even in the course of the inhibition testing itself.

Our *perfringens* organism, unlike one of the strains tested by Stack and Morgan ('49), did not destroy the B antigen. The B secretor antigen was, as we noted, apparently untouched, but the anti-H component as indicated by *Ulex*, either was somewhat reduced in amount, or the cells used as indicators were differentially agglutinated due to enzymatic influence.

Parenthetically, it is of interest to note that another enzyme elaborated by the *perfringens* organism, known as collagenase, is capable of collagen destruction, and may thus modify the structure and consistency of bone and further the entrance of the antigen-destroying enzyme.

#### CONCLUSIONS

The accuracy of bone typing is seen to rest upon the amount and chemical integrity of antigenic remains in bone, undestroyed and untransformed by bacterial enzymes, and upon the reliability and specificity of indicator tests. The inhibition test has been seen to offer numerous potentialities for error in unequal or total destruction of test antisera by contaminants present, in unequal non-specific absorption leading to false interpretations, the presence of adventitious antigenic elements which cannot be distinguished from blood group substances, and the possibility of the influence of bacterial enzymes upon the test-cells themselves.

The secretor status of the individual tested was not found to relate to the accuracy of bone typing.

In conclusion, results obtained in the typing of aged bone or stains by the inhibition test do not appear reliable under some conditions. It is likely that material such as the Aleut bone typed by Candela ('39), mummified tissue typed by the Boyds ('37), and such dessicated and/or naturally refrigerated material, not in contact with damp soil, is accurate, or enough so to use with security in historical studies.



The further efficiency of bone typing will rest upon renewed attempts to find antigen-specific indicators, possibly such as paper chromatography or precipitin testing, which will eliminate the many disadvantages of antibody inhibition.

#### ACKNOWLEDGMENT

This research was carried out with funds received from the Q.M. Research and Development Command under Project 7-64-12-004C.

#### LITERATURE CITED

- BOYD, W. C. 1933 Blood grouping by means of preserved muscle. *Science*, *78*: 578.
- 1939 Blood grouping reactions of preserved bone and muscle. *Amer. J. Phys. Anthropol.*, *25*: 421-434.
- BOYD, W. C., AND L. G. BOYD 1934a Group specificity of dried muscle and saliva. *J. Immunology*, *26*: 489-494.
- 1934b An attempt to determine the blood groups of mummies. *Proc. Soc. Exp. Biol. and Med.*, *31*: 671-674.
- 1937a Blood grouping in forensic medicine. *J. Immunology*, *33*: 159-172.
- 1937b Blood grouping tests on 300 mummies, with notes on the precipitin test. *J. Immunology*, *32*: 307-319.
- CANDELA, P. B. 1936 Blood group reactions in ancient human skeletons. *Am. J. Phys. Anthropol.*, *21*: 429-432.
- 1937 Blood group determinations upon Minnesota and New York skeletal material. *Am. J. Phys. Anthropol.*, *23*: 71-78.
- 1939a Blood group determination upon the bones of thirty Aleutian mummies. *Am. J. Phys. Anthropol.*, *24*: 361-383.
- 1939b Blood tests on stains, mummified tissue, and cancellous bone. *Am. J. Phys. Anthropol.*, *25*: 187-214.
- 1940 Reliability of blood tests on bones. *Am. J. Phys. Anthropol.*, *27*: 367-381.
- GETTLER, A. O., AND H. E. KRAMER 1936 Blood grouping in forensic medicine. *J. Immunology*, *31*: 321-329.
- ISEKI, S., AND S. OKADA 1951 On a specific enzyme which decomposes A substance. *Proc. Japan. Acad.*, *27*: 455-458.
- ISEKI, S., AND S. TSUNODA 1952 On a bacterial enzyme which specifically decomposes O substance. *Proc. Japan. Acad.*, *28*: 370-373.
- ISEKI, S., AND S. MASAKI 1953 Transformation of blood group substance by bacterial enzyme. *Proc. Japan. Acad.*, *29*: 460-465.
- 1955 Chemical actions of O and A specific enzymes on the respective blood group substances. *Gunma. J. Med. Sci.*, *4*: 105-116.
- ISEKI, S., AND T. IKEDA 1956 On bacterial enzymes specifically decomposing group B substance. *Proc. Japan. Acad.*, *32*: 201-205.

- SALAZAR MALLEN, M. 1951 Estudio inmunologico de restos oseos antiguos. Gac. Méd. Méx., 81: 122-127.
- SCHIFF, F. 1935 Uber den abbau gruppenspezifischer substanzen bakterien. Klin. Wochenschrift, 14: 570-571.
- 1939 An ecto-enzyme of *Clostridium welchii* which decomposes blood group specific substance A. J. Infect. Dis., 35: 128-133.
- STACK, M. V., AND W. T. J. MORGAN 1949 The preparation and properties of enzymes from *Clostridium welchii* (type B) filtrates which destroy blood group substances. Brit. J. Exp. Path., 30: 470-483.
- THIEME, F. P., C. M. OTTEN AND H. E. SUTTON 1956 A blood typing of human skull fragments from the Pleistocene. Am. J. Phys. Anthropol., 14: 437-444.



# ESTIMATION OF SKELETAL AGE FROM COMBINED MATURATIONAL ACTIVITY

THOMAS W. McKERN

*Environmental Protection Research Division QM Research and  
Engineering Center, Natick, Massachusetts*

## FOUR FIGURES

The calculation of age at death from the observed status of skeletonized remains is one of the principal identification methods provided by the physical anthropologist. While the application of this technique has long proved invaluable to both military and civilian agencies involved in identification work, there exist inherent limitations which arise partially from the subjective nature of the method as well as the lack of well documented skeletal series with adequate age coverage. Within the framework of subjective method, it is generally believed that because of the high variability of individual maturative events more precise age estimations may be derived by pooling all available criteria and giving final age assessments as crude averages. Thus, as research on the maturative activity of new areas is completed, they are added to the list of ageing criteria on the assumption that each new addition tends to further minimize excessive individual weighting. However, the validity for combining many individual observations has never been objectively tested for methods of age identification.

At present, this pooling procedure is followed in instances where the complete skeleton is available as well as for those cases where only fragmentary remains are recovered. To the identification specialist, it would be particularly advantageous to know if there are certain skeletal areas that are more critical than others for age assessments or whether reliable iden-

tification must depend on the most complete coverage for each individual specimen. Whereas it is difficult to test the comparative value of single growth areas, it is possible to test the reliability of age prediction for selected groups of these areas. Based on an analysis of data collected on a thoroughly documented sample of American war dead, it is the purpose of this paper to test the application of the concept of combined maturation as it relates to estimations of skeletal age.

#### MATERIAL

The present analysis is based on data collected by Dr. T. D. Stewart on 450 skeletonized and identified U. S. war dead (ages ranged from 17 to 50 years) which were being repatriated from North Korea during the fall of 1954 (complete details on this sample may be found in McKern and Stewart, '57).

#### METHOD

Of the total number of growth areas in the skeleton, 11 sutures and 38 epiphyses were selected to represent total maturation for ages 17 to 25. The analysis was not carried beyond the 25th year because, with the exception of the metamorphosis of the symphyseal surface of the pubic bone and the union of the epiphysis at the medial end of the clavicle, postcranial ossification is essentially complete by that year. Also, because of the specialized nature of the ossification of the symphyseal surface of the pubic bone, it was thought best to omit the pubic symphysis from the list of postcranial events and treat it as a separate area.

The particular status of maturational progress for each skeletal event was scored on a scale of 1 to 5 (a modification of the familiar scoring system of 0 to 4 purely for statistical purposes):

- 1 = non-union
- 2 = one quarter united
- 3 = one half united
- 4 = three quarters united
- 5 = complete union



Each cranial suture was treated as a single unit rather than a number of related divisions, i.e., the saggital was not broken down into bregmatica, obelica, etc., but was scored on the basis of its combined activity. Also, the epiphyses of the vertebral centra and rib heads were scored as a whole.

After the initial scoring of events was accomplished, a total maturation score for each individual skeleton was derived simply by summing the scores for all events. Thus, individual total scores could be associated with known chronological age. However, to test the relative merits of various growth area combinations, the total number of maturational events was arranged in several ways:<sup>1</sup>

Group I. Sampling of total maturation: 11 sutures (including vault, circummeatal and accessory) and 38 postcranial epiphyses.

Group II. Sampling of 38 postcranial epiphyses.

Group III. Sampling of 12 postcranial epiphyses:

Humerus, prox.	Clavicle, med. end
Humerus, med. epicondyle	Scapula, acromion
Radius, dist.	Vertebral centra
Femur head	Iliac crest
Femur, dist.	Ischial ramus
Tibia, prox.	Sacrum, lat. joints

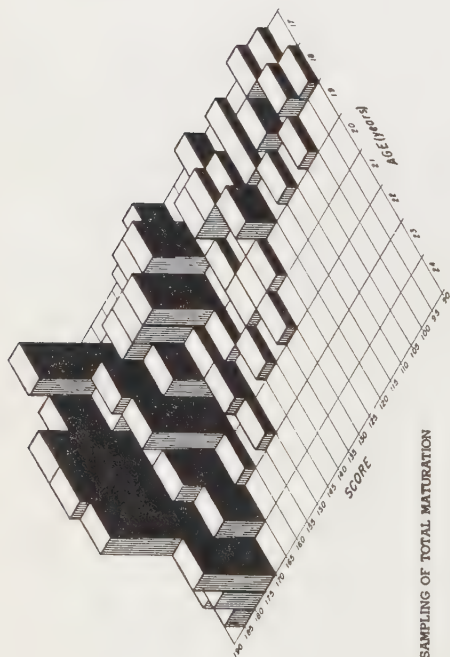
Group IV. Total number (15) of long bone epiphyses.

Group V. Nine postcranial epiphyses selected on the basis of the regularity of their overall pattern of maturation and on the distinctive nature of their observed stages of terminal union:

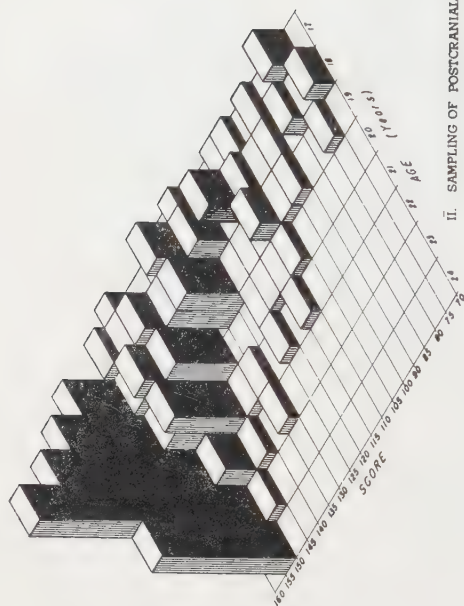
Humerus, prox.	Clavicle, med. end
Humerus, med. epicondyle	Iliac crest
Radius, dist.	Sacrum, lat. joints
Femur head	Sacrum, 3-4 joint
Femur, dist.	

Combined scores were calculated for each of these groups and figure 1 shows bivariate frequency distributions of age and total score for the three Groups, I, II and V, which proved to be the best predictors.

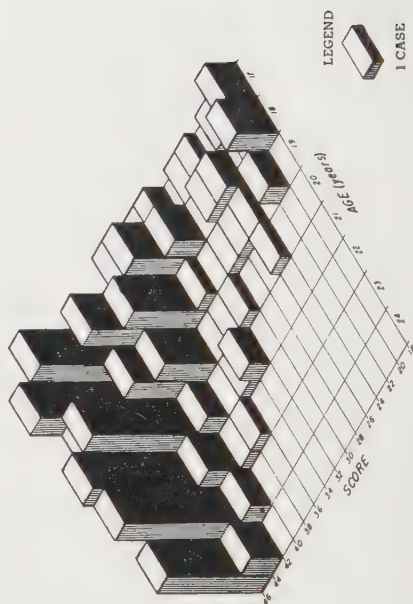
<sup>1</sup> Actually, some 15 skeletal combinations were tested and of these 15, five were selected for this paper as being most suitable.



I. SAMPLING OF TOTAL MATURATION



II. SAMPLING OF POSTCRANIAL EPIPHYSES



V. NINE KEY POSTCRANIAL EPIPHYSES

## GROUP COMPARISON

Our interest in this paper is primarily in the degree of relationship between score and age for each group. Since the plotted data appeared to be curvilinear, a correlation ratio for curvilinear relationships ( $\eta$ ) was calculated (McNemar, '50, p. 183). The  $\eta$  values for all groups are reproduced in table 1.

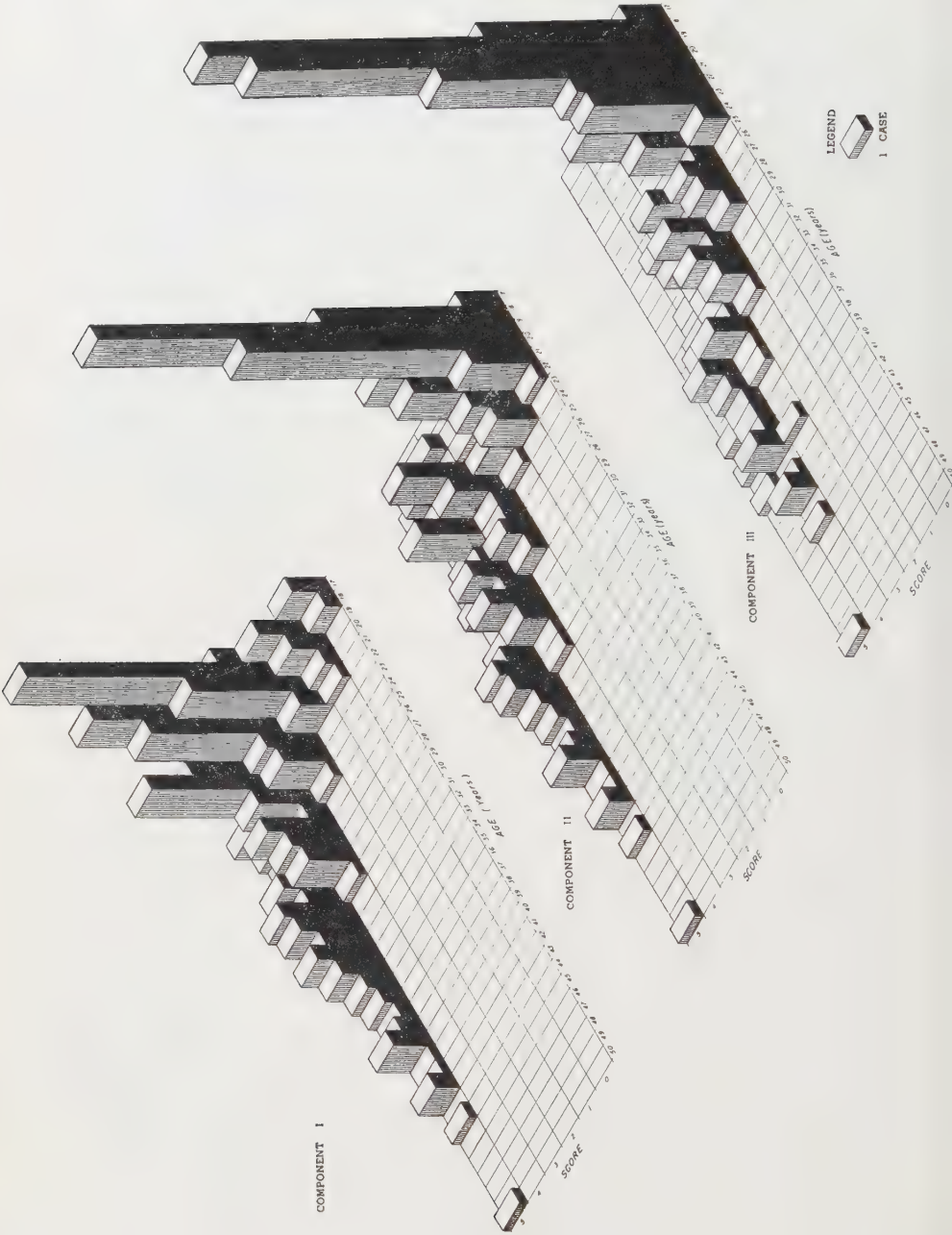
The correlation ratio values in table 1 show that there are differences between the various groups of growth events. For example, an  $\eta$  of .74 (calculated for Group I) indicates that 54 percent of the age variance is associated with the variance

TABLE 1  
*Eta values for the five growth area Groups*

GROUP	NO. OF EVENTS	ETA
I	49	.74
II	38	.75
III	12	.68
IV	15	.57
V	9	.76

in score, whereas an  $\eta$  of .57 (calculated for Group IV) refers to a relationship in which only 32 percent of the age variance is associated with variance in score. In other words, Groups I, II and V show the best relationships and thus would be the best age predictors. Among these three, Group V represents the least number of events (9, as against 49 for Group I and 38 for Group II), and in cases where the complete skeleton is available, an age estimation based on Group V would be more rapidly and easily calculated than it would be for Groups I or II. At the same time, of the Groups composed of fewer events (Groups III, IV and V), Group V is alone in its ability to predict a reliable age. Thus, Group V represents a small number of critical growth areas from which adequate age estimations can be calculated.

Previous work has indicated that the symphyseal surface of the pubic bone is a better age predictor than any other single skeletal event (Todd, '20; Brooks, '55). Recently, a new sys-



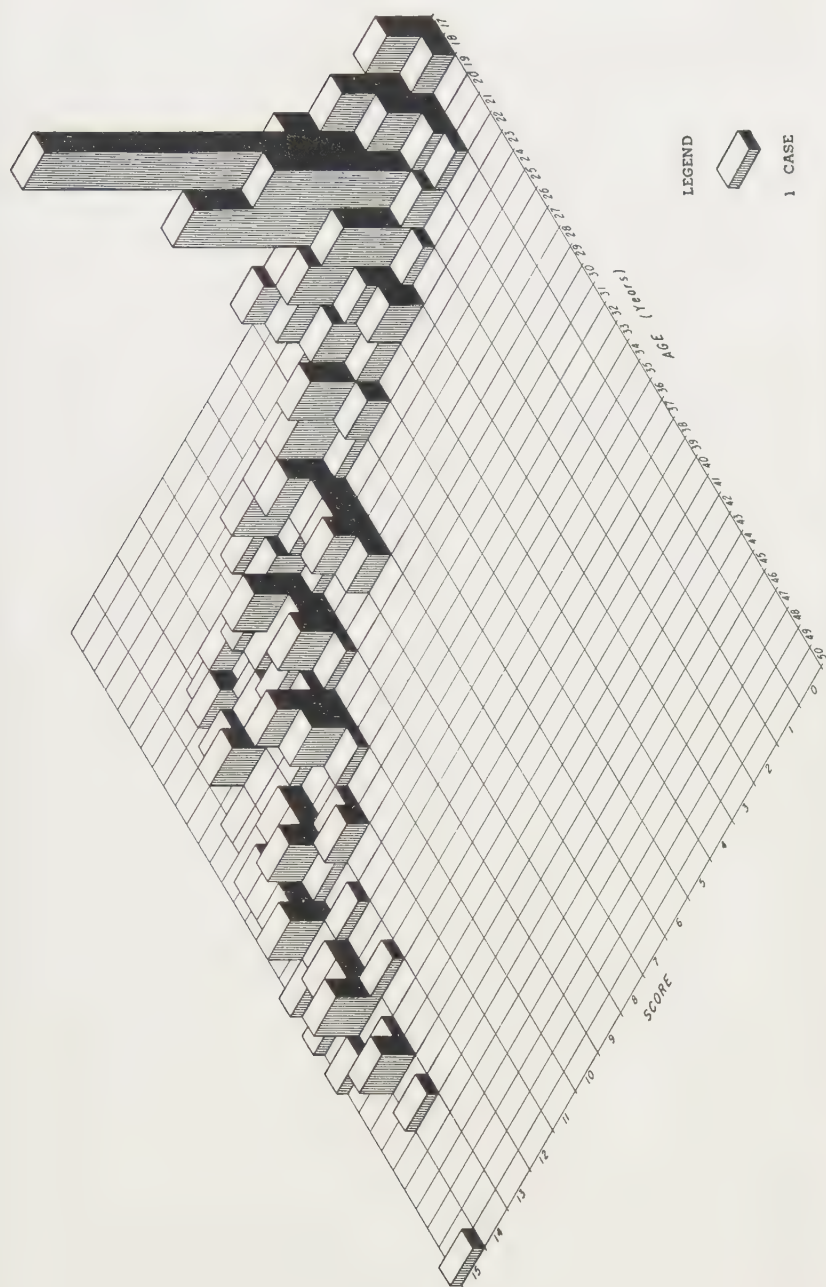


Fig. 3 Bivariate frequency distribution of age and total symphyseal component score.



tem for determining age was presented which is based on the developmental progress of three independent symphyseal components (McKern, '56; McKern and Stewart, '57). Since the foregoing Groups and the symphyseal data were extracted from the same skeletal series, it is possible to calculate a correlation ratio for the symphyseal formula scores which can be compared to the Group ratios. A comparison of this nature (based only on data from the same series) leaves much to be desired but is unavoidable since comparable information on the pubic symphysis has not been reported elsewhere. Figure 2 shows a bivariate frequency distribution of age and score for each of the symphyseal components. The individual component scores were then summed and figure 3 shows the distribution for age and total component score for the complete series (17 to 50 years). By using only the data for ages 17 to 25, a correlation ratio of .86 was calculated for the symphyseal material. Compared to the eta's of table 1, the symphyseal scores, representing a single growth area, indicate a much better relationship than any of the five Groups.

It is apparent that the indiscriminate pooling of observational values can give variable results which, in most cases, does not aid accurate identification. This is illustrated further in figure 4. In a given instance of age identification where the complete skeleton is on hand, the observer could arrive at two separate age estimates; one calculated from the total postcranial scores (Group II) and one from the pubic symphysis. The observer must choose between: (1) combining and averaging the two values, (2) weighting one value over the other, or (3) excluding one completely. Figure 4 illustrates the relationships between the mean predicted ages calculated from Group II and symphyseal scores, the average of the two mean predicted ages, and the known age. With the exception of ages falling between 19.5 and 20.5 years, where there are no significant differences, the observer would obtain more accurate age assessments by calculating age from the symphyseal

surface of the pubic bone and ignoring all other growth areas. Therefore, if combining observed values is indicated, a careful selection for critical events must be made to insure most accurate results. From the foregoing analyses, such a selection would be represented by the events comprising Group V. As for critical single events, the importance of the symphyseal surface of the pubic bone has been fully established.

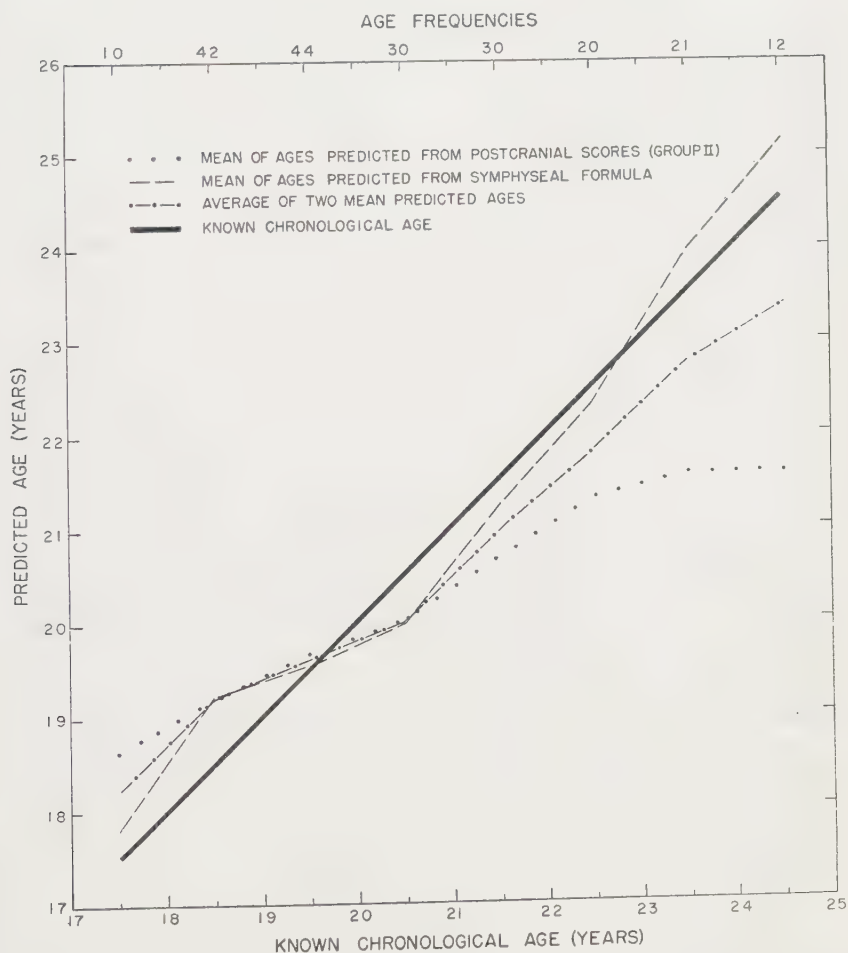


Fig. 4 Graph showing the relationships between mean predicted ages, the average mean predicted age, and known age.

## SUMMARY AND CONCLUSIONS

The degree of relationship between combined maturational score and age has been tested for five groups of skeletal growth areas. The data indicate that an age estimation derived from the combined maturational activity of a small group of critical growth areas is as reliable as an estimation based on the total number of maturative events. To the identification specialist, this information means that instead of the usual practice of emphasizing complete skeletal coverage, dependable age estimations can be obtained from the combined maturational activity of a small number of critical areas. Also, because of the tested reliability of the symphyseal surface of the pubic bone, the use of other ageing criteria is necessary only where the pubic symphysis is damaged or missing (at least for age groups over 17 years).

## ACKNOWLEDGMENTS

The author is indebted to Dr. T. D. Stewart for his helpful advice in the preparation of this study and to Miss Ella Munro for her expert aid in the statistical analysis of the data.

## LITERATURE CITED

- BROOKS, S. T. 1955 Skeletal age at death: The reliability of cranial and pubic age indicators. *Am. J. Phys. Anthrop.*, 13: 567-597.
- MCKERN, T. W. 1956 The Symphyseal Formula: a new method for determining age from pubic symphyses. *Am. J. Phys. Anthrop.*, 14: 388 (abst.).
- MCKERN, T. W., AND T. D. STEWART 1957 Skeletal Age Changes in Young American Males. Quartermaster Research and Development Center. Environmental Protection Research Division, Technical Report EP-45.
- MCMENAR, Q. 1950 Psychological Statistics. John Wiley and Sons, Inc., New York.
- TODD, T. W. 1920 Age changes in the pubic bone. I: Male White pubis. *Am. J. Phys. Anthrop.*, 3: 285-334.

## REVIEW

ANALYSE DE LA VARIATION DES CARACTÈRES PHYSIQUES HUMAINS EN UNE RÉGION DE L'AFRIQUE CENTRALE: RUANDA-URUNDI ET KIVU. By J. Hiernaux. *Annales du Musée Royal du Congo Belge. Série in 8.° Sciences de l'Homme, Anthropologie.* Vol. 3. pp. 1—131, pl. I—VII. Tervuren, 1956.

This admirable paper makes a considerable contribution to the theory and method of the comparative physical anthropology of populations ("traditional" physical anthropology), through its awareness of problems, clarity of purpose and ideas, and intelligent handling of analysis. It is a magnificent demonstration of what can be done, compared with what has been done, using familiar kinds of material. It represents about a generation's advance from what such late masters as Hooton or Pearson were trying to do within the limitations of the methods of their day. Hiernaux has not invented anything. He has simply understood the modern literature, and what he was doing. But he has contributed many valuable ideas, suggestions and conclusions, which can be indicated broadly under the headings of choice of material, method of analysis, and synthesis of genetical and biometrical results.

The author is, of course, well acquainted with his area, as a hematologist and general medical researcher. He knows the pertinent traditional and linguistic information as well. He has recognized the particular advantages for study of Ruanda-Urundi and Kivu, where there exist a number of tribes of the general Negro type, genetically more or less isolated at present but largely from a common source in Uganda. They are distributed in two ecological zones or biotypes—upland savanna near the lake chain (Albert, Edward, Kivu, Tanganyika) and lower shade forest lying along the western slope of the first zone—as well as two other main populations: the earlier hunting pygmies, throughout the area, and the later, very tall cattle aristocracy, the Batutsi of Ruanda-Urundi. All this gave him a chance to make multiple comparisons between environments, as tested against the differences within environments, and to relate physical and serological differences between tribes to the degree of genetic isolation among them. He obtained suitable samples from 15 populations, virtually all the important groups in

the area, measuring about 2,000 men altogether. He did not, as we have been wont to do, simply measure Africans where the measuring was good: rather, he considered his problem, decided what areas to sample, and sampled accordingly.

As a weapon, he used Mahalanobis' generalized distance, or D statistic: he rejects the arguments of others that the labor of calculation is not worth getting a pure measure of divergence, taking the original view that if the data are worth taking pains in collection they are worth taking pains in analysis. By using the D statistic rigorously and thoroughly in connection with several different problems, he demonstrates that it is surprisingly sensitive and effective. He investigates the problem (apparently for theoretical purposes) of whether a "classification," in the old sense, can be arrived at: whether groupings can be found, within which each population diverges less from its congeners than from any in any other grouping. The answer is no: only the Tutsi are clearly segregated from all others, the rest being unclassifiable. Though anthropologists have abandoned ideas of such clear classification with their connected implications (original racial purity, morphological types, Dixonian races, etc.), this is a highly developed demonstration of the point. Next, he investigates other kinds of relationship, finding that five of the eastern groups all show the same gradient of distinction from the ten others; i.e., a high reliability is evident. The five are the Shi, Hutu of Urundi, Hutu of Ruanda, Tutsi of Urundi and Tutsi of Ruanda, conforming perfectly to a model of bi-directional gene flow from Tutsi of Ruanda at one end to Shi at the other, fitting historical and other information as well. The point of all this is that such resoundingly clear information would be impossible if something like the D statistic were not available to make the basic data, from many different measurements, comprehensible.

As to the biometric and genetic approaches, he has this to say: "Many anthropologists, impressed by the theoretical advantages of the use of gene frequencies in systematics, are apt nowadays to contrast the genetics and the biometrics of populations in terms of one, refined, discipline allowing us to grasp the biological reality, opposed to another, outworn, discipline incapable of penetrating beyond the phenotype." Hiernaux asserts that his analysis shows the latter is as useful as the former, and that both are necessary for certain problems, since the investigation of environmental effects calls for traits running the gamut from those which are immune to such effects in the individual (like blood groups) to those which on the other hand betray little influence of heredity. He points out certain advantages in metrical traits: the choice is wider than in



single gene traits, and the latter have not yet been provided with a suitable measure of divergence for summing group differences. (He uses a sum of chi squares). He demonstrates the importance of a synthesis in practical fashion, by showing that the number of genetic barriers between any two tribes correlates equally well with the D statistic and with the combined chi square on ABO, MN and sickling. As to environment, the D statistic shows a general distinction in morphology between ecological zones, but leaves open whether environment or differences of origin plus admixture is responsible; the serology rules out the latter but would not have suggested the former; therefore only the simultaneous use of both methods makes possible a decision.

There are various other illuminating findings: for example, the number of significant differences in 36 tribal comparisons rises sharply from the MN series through the ABO to the sickling gene, indicating their relative stability or instability vis-à-vis probable natural selection. The above review only suggests the content of this stimulating and suggestive monograph, and all physical anthropologists are urged to study it.

W. W. HOWELLS  
*Harvard University*



## REVIEW

PREHISTORIC MAN IN DENMARK (A Study in Physical Anthropology). By Kurt Brøste, J. Balslev Jørgensen, C. J. Becker and Johannes Brøndsted. Two Vols; Vol. I, 159 pp. 46 figures, 122 tables. Vol. II, 439 pp. 265 plates. Einar Munksgaard Publishers, Copenhagen, 1956. 230.00 Dan. Cr.

With the publication of these two handsome volumes, covering the Stone Age and the Bronze Age, a better understanding not only of the prehistory of Denmark but of all northern Europe is available. Though the initiating author, Kurt Brøste, did not live to see his handiwork, J. B. Jørgensen and the collaborating archaeologists have successfully concluded this portion of the study. A third volume is planned, to include Iron Age skeletons, the Viking era, and data on pathologies, trepanations, discrete traits, possibly the blood types, and comparisons involving the statistical estimation of distance, and with the pertinent archaeological data for Denmark and for Europe.

Two outstanding features of this publication are the superb plates and the precise archaeological data included with each group of skulls. This accompanying data is printed with the plates in Vol. II so that each skull may be studied without turning back to the archaeological introduction in Vol. I. Also as archaeological researches in Denmark have been both thorough and long standing, the reference to soil types as well as tombs and artifacts are complete. Thus, various sampling problems can be discussed in interesting detail and the effect of different kinds of inhumation on skeleton preservation is made evident. The photographs are of such quality that sutural details can easily be discerned. For the first time each of the important Borreby skulls, excavated in 1859 by J. Worsaae and referred to by many anthropologists from Rudolph Virchow and H. A. Nielson to C S. Coon, is shown. All 265 skulls of the total series of Mesolithic (4), Early Neolithic (4), Middle Neolithic (47), Late Neolithic (72), Middle or Late Neolithic (133) and Early Bronze Age (5) described in the text are represented in plates. The precise determination of the archaeological context in relation to detailed morphological description, plus other evidences of effective collaboration between physical anthropologist and archaeologist has resulted in reliable information concerning the kinds of people and their cultures in prehistoric Denmark.

The classical anthropometric description is thorough. Following the techniques of Martin as many as 91 characters have been determined for each skull. Each specimen, including long bones, has been measured three times, and the appropriate statistical constants have been computed. In addition, all the measurements, diameters, indices and angles, have been included in tables. As a consequence, it is possible to regroup the specimens for analytical purposes, thus we are provided with a work book containing the original data on a large series of well dated skeletons.

A number of important findings emerge. The Mesolithic skulls do not show any significant relationship to Upper Paleolithic man. The populations of Middle and Late Neolithic Ages were the same and no discernible influence from the immigrating Battle-Axe peoples is in evidence. Stature increased, in the Late Neolithic, and the skeletons became more slender, however, intermembral proportions remained much the same and the shape of the skull remained essentially constant. Various characters were examined for intercorrelations and little was found, rendering the formulation of type subdivisions impractical. This is an exceedingly valuable portion of the study and provides a refreshing respite from the older literature which is often replete with typologies.

All anthropologists, archaeologists and related students of pre-history are indebted to these authors, to the Carlsberg Foundation for contributing to the printing of such a large number of tables and plates, to the Rask-Ørsted Foundation and Mr. W. E. Calvert for the excellent translation. This is a rich source book and the best possible substitute for an actual examination of the specimens in Denmark. Publication of the third volume is imperative.

W. S. LAUGHLIN  
*University of Wisconsin*

## BOOK NOTES

### RACE AND CULTURE CONTACTS IN THE MODERN WORLD.

By E. Franklin Frazier, pp. ix + 338. Alfred A. Knopf, New York, 1957.

This book recounts the history of race contacts since the period of European expansion. The data are presented largely by country under several broad headings, namely, Ecological Organization, Economic Organization, Political Organization, and Social Organization. As a sociologist, Frazier is little concerned with the biological consequences of the history he describes, yet the historical data are extensive and useful in understanding the modern population which have been produced by these racial contacts and migrations. The book suffers from having no collected bibliography with citations being limited to footnotes.

---

### THE DARWIN READER. Edited by Marston Bates and Philip S. Humphrey, pp. ix + 470, \$6.75. Charles Scribner's Sons, New York. 1956.

Bates and Humphrey have collected and selected from many of Darwin's most interesting works a representative anthology designed to be attractive to students or others unlikely to read the original works in their entirety.

---

### CUMULATIVE INDEX TO CURRENT LITERATURE ON ANTHROPOLOGY AND ALLIED SUBJECTS.

Vol. II, January-June, 1956. Department of Anthropology. Government of India. Indian Museum, Calcutta. 1957.

By initiating this series, the Indian Museum has made a substantial contribution to all of anthropology. The prompt appearance of Volume 2, indexing articles from 97 periodicals, and the promise of a continuing series is most welcome. Articles and journals related to physical anthropology are well covered. The practical value of this index to the profession might be enhanced if it were made regularly available by subscription.



THE EVOLUTION OF HUMAN NATURE. By C. Judson Herrick. pp. x + 506, \$7.50. University of Texas Press, Austin. 1956.

The author, a great neuro-anatomist, has divided his book into two parts: "The Evolution of Behavior" and "The Evolution of Brains." The first is sub-titled "Biological Factors of Psychobiology" and the second the "Neurological Factors of Psychobiology." Our knowledge of the actual course of psychological evolution leading to the human state is slight and Herrick adds nothing to the historical evidence. His book is not an historical evolutionary study but rather is more speculative and philosophical about man's present nature and future. This is an important book in that it recapitulates the thoughts of an outstanding biologist on a fascinating topic.

---

PICA. By Marcia Cooper, pp. viii + 114, \$6.50. C. C. Thomas, Springfield 1957.

Pica refers to the habit of some persons or groups of eating various inorganic materials, such as clay or ashes. In the study reported by the author, pica was discovered in 21.9% of 784 preschool Negro and White children from a poor district in Baltimore. The frequency is analyzed by sex, race, material eaten, I.Q., birthweight, medical history, age at weaning, nutritional background and family income. The author reviews the literature on this curious subject in the first chapters of the book and concludes from her study that poor nutritional background may be an underlying factor in pica.

---

PRIMATES (Comparative Anatomy and Taxonomy). III. Pithecoidea. Platyrrhini.-Hapalidae. By W. C. Osman Hill, pp. xix + 354, \$13.50. University Press, Edinburgh, and Interscience Publishers, New York. 1957.

This is the third in the planned series of seven or eight volumes dealing with the whole order Primates. Straus has reviewed (A. P. A. 14: 668-673, 1956) the first two volumes which dealt with the lemurs and tarsiers. As at least one other monograph on the New World primates is planned, we are now merely noting the appearance of the first volume on these monkeys and hope that an extensive review covering the whole infra order Platyrrhini can appear later.

This present volume devotes the first 76 pages to the general characteristics of the simians, and the next 37 to those of the New World monkeys before turning finally to the marmoset family. The family Callimiconidae, represented by the single genus *Callimico* is also mentioned. Twenty seven plates and 102 figures are included. The next volume is planned to cover the Cebidae.

---

HEALTH SERVICES FOR AMERICAN INDIANS. U. S. Dept. of Health, Education and Welfare. Public Health Service Publication No. 531, \$1.75. Superintendent of Documents. Washington 25, D. C. 1957.

This document was prepared by the Public Health Service at the request of the Appropriations Committee of the House of Representatives. It describes the present health status of the American Indians using data largely gathered by field workers. While no anthropometric or genetic data are included, the extensive demographic and health information is of interest to any anthropologist concerned with the American Indians.

---

RAZZE E POPOLI DELLA TERRA. IV. Oceania-America-Indici Generale. By Renato Biasutti, pp. vi + 811, 2nd Edition. Unione Tipografico-Editrice Torinese, Torino. 1957.

The fourth volume completes the second edition of the original set. The series gives a truly impressive encyclopedic collection of ethnographic material organized by geographic areas. These books are extensively illustrated, with many maps and color plates, and are well printed and bound.

---

THE MONKEY KINGDOM. By Ivan T. Sanderson, pp. 200, \$6.95. Hanover House, Garden City. 1957.

This handsomely printed book contains 78 pictures of primates, 30 of which are in color, 12 drawings and 9 maps illustrating the geographic distribution of these creatures. In addition, Sanderson has prepared a taxonomic list giving the scientific and popular names for each family and sub-family and the approximate number of sub-

species in each currently recognized. The text is extensive and gives descriptive morphology, habits and interesting sidelight stories about many of the forms. This is designed to be a popular book but gives a description of the order Primates that is sufficiently detailed to serve as a beginning text for serious students.

---

LES POPULATIONS DU CAMBODGE (*Anthropologie Physique*).

By Georges Olivier, pp. 164, 1600 fr. Masson et Cie, Paris. 1956.

A study dealing with the physical anthropology of 3 Cambodian populations, the Khmers, Chans and "Autochthonous," is published under the auspices of the Societe d'Anthropologie de Paris and includes a preface by H. Vallois. The samples measured were 440 Khmers and 92 Chans with 50 Vietnamese and 30 aboriginals of Annam used as comparative series. Standard anthropometry, observations and descriptive indices are given for each sample group and ABO blood typing was done on 500 subjects (29%-O, 24%-A, 39%-B and 8%-AB). The author concludes that the Khmer and Chan are old indigenous populations but with a slightly different history of mixture with immigrating groups. The group labeled by the author as autochthonous is small, highly variable, widely distributed and not readily definable. All three groups are classified as Indonesian and distinct from the Vietnamese.

---

POPULATION GENETICS: The Nature and Causes of Genetic Variability in Populations. Cold Spring Harbor Symposia on Quantitative Biology, vol. 20, pp. xvi + 346, 115 fig., 3 plates, \$8.00. The Biological Laboratory, Cold Spring Harbor, New York. 1955.

Volume 20 in this annual series of symposia on quantitative biology is especially interesting to anthropologists as it deals with the nature and the causes of variability—a subject of traditional concern to the profession. The subject is exhaustively and expertly covered by the 32 papers included in the published record of the symposium which took place in the summer of 1955. The papers are grouped under several headings; namely, General Population Genetics Theory, Theory of Quantitative Genetics, Selection in Plants, Selection in Animals, Genetic Variability and Polymorphism,

Populations in Time and Space, and Integration of Genotypes. Only one of the papers deals exclusively with man; that of A. C. Allison on Aspects of Polymorphism in Man, but this does not reduce the relevance of many papers to the study of human populations. R. Ceppellini, in discussing Allison's paper, gives a resume of his most interesting findings on the frequency of thalassemia and blood types in 4 Sardinian villages which suggest that selection by malaria may be important. T. Dobzhansky, whose paper introduces the symposium, gives a review of some fundamental concepts and problems.

The following (Polish with English or German summary) has been received from the Polska Akademia Nauk, Zaklad Antropologii. Wroclaw:

- No. 13 THE ANTHROPOLOGICAL SURVEY OF SELESIA, RYBNIK DISTRICT. By K. Stolyhwo, B. Jasicki and P. Sikora, pp. 560. 1956. Anthropometric measures and indices on 5,609 males and 5,247 females, 20 to 60 years old, from 102 villages are reported. All the data for each person is published.
- No. 20 APPLICATION OF PERKAL'S INDICES TO THE CHARAKTERIZATION OF THE BUILD OF BOXERS. By Halina Milicer, pp. 85. 1956. The indices of Perkal are applied to analyze the build of 130 boxers. The methodology giving a "biological characterization" of the whole body is something of special interest.
- No. 23 DIE ANTHROPOLOGISCHE STRUKTUR DER MASUREN. By Brunon Miskiewicz, pp. 63. 1956. Measurements on a sample of 611 are given in detail plus summary tables describing this East Prussian group.
- No. 25 GRAVES FROM THE BRONZE AND EARLY MIDDLE AGES. By Brunon Miskiewicz, pp. 91. 1956. Listed are 84 measurements and indices on each of 48 skulls from 7 different sites.
- No. 26 FURTHER INVESTIGATIONS ON THE ERUPTION OF THE PERMANENT TEETH AS A CRITERION FOR THE EVALUATION OF THE DEGREE OF DEVELOPMENT OF THE HUMAN ORGANISM. By Stanislaw Panek, pp. 50. 1956. Data on tooth eruption, body weight and stature for 1343 boys and girls from 4-1/2 to 16-1/2 years of age are reported and analyzed.

*One Hundred Years of Polish Anthropology. 1856-1956.*

- No. 32 IZYDOR KOPERNICK. By Michael Godycki, pp. 40. 1956.
- No. 36 ANTHROPOLOGIE AUSSERHALB DER UNIVERSITATSZENTREN. By Jan Czekanowski, pp. 47. 1956.
- No. 34 LEMBERGER SCHULE. By Jan Czekanowski, pp. 71. 1956.
- No. 38 WILNO CENTRE. By M. Reicher and W. Sylwanowicz, pp. 19. 1956.

F. P. THIEME





P R O C E E D I N G S  
of the  
TWENTY-SIXTH ANNUAL MEETING  
OF  
THE AMERICAN ASSOCIATION  
OF PHYSICAL ANTHROPOLOGISTS

The twenty-sixth annual meeting of the Association was held with the tenth annual meeting of the American Society of Human Genetics in Ann Arbor, Michigan, Friday through Sunday April 12-14, 1957 by invitation of the Departments of Anthropology and of Human Genetics of the University of Michigan.

In addition to the seven sessions for contributed papers, the joint meetings included: The Wenner-Gren Supper Conference on "Natural Selection in Man;" the University of Michigan Luncheon addressed by Dr. Albert C. Furstenberg, Dean of the Medical School, and Dr. Charles E. Odegaard, Dean of the College of Literature, Science, and the Arts; the annual dinner of the two Societies, followed by Dr. Curt Stern's Presidential Address of the ASHG "On 'Porcupine Men' and Hairy Ears, or the Alleged Sins of the Y-Chromosome."

The Executive Committee of the AAPA held its regular annual meeting the evening of April 11, 1957.

BUSINESS MEETING, APRIL 13, 1957

The minutes of the 25th annual meeting were approved as printed (AJPA, n.s., 14: 349-404, 1956).

President Trotter announced the following appointments to committees: *Nominating Committee* (1958): Frederick S. Hulse, Frederick P. Thieme, and William L. Straus, Jr., Chairman. *Viking Fund Award Committee* (1957-1958): J. Lawrence Angel, Bertram L. Hanna, William W. Howells, W. W.

Greulich, T. Dale Stewart, and Mildred Trotter, Chairman. *Auditing Committee* (1957): E. Carl Sensenig and F. Clark Howell, Chairman. *Resolutions Committee* (1957): Marshall T. Newman and William S. Laughlin, Chairman.

Russell W. Newman was appointed representative of the Association to the AAAS Council for the term ending December 31, 1959. Kalevi P. Koski and Albert A. Dahlberg were appointed representatives to the XIIth International Dental Congress of the International Dental Federation to meet in Rome, September 7-14, 1957.

Stanley M. Garn was appointed to represent the Association at the inauguration of the eighth President of Ohio State University on April 29, 1957.

The following new members were approved by the Executive Committee on April 11, 1957 and were elected to membership by unanimous vote:

Bob Alberts  
J. E. Anderson  
William Marvin Bass, III  
Count Bernardino del Boca di  
Villaregia  
J. O. Buswell III  
L. De Castro Faria  
Shin yo Chang  
Nicholas Hotton III  
Jørgen Balslev Jørgensen  
L. A. Kerwood  
P. Liptak  
Lennart Lysell  
Paul A. Moody  
Donald Harvey Morris  
Peter W. Nichols  
Kenneth Page Oakley

Richard A. Platt  
A. H. Craven  
Adelaida G. de Diaz Ungria  
William F. Eads  
Aaron Elkins  
Santiago Carlos Genoves  
Eugene Giles  
Georges A. Heuse  
Lester J. Ray  
Torsten Romanus-Kjellgren  
Alex F. Roche  
Richard G. Snyder  
Hisashi Suzuki  
Christy G. Turner II  
Malcolm E. Turner  
H. Henry Weisengreen  
Durgesh Kumar Verma

We regret the loss by death of two members during the year: Dr. Hubert S. Howe of New York City, and Captain Harry C. Meyers, Jr., of Wright-Patterson Air Force Base.

The present membership of the Association is 419. There were 84 members in 1930, 153 in 1942, 300 in 1952, 404 in 1956.

The Report of the Treasurer, and that of the Auditing Committee presented by F. Clark Howell, were approved.

## REPORT OF TREASURER — FISCAL YEAR 1956-1957

*Operating Account:*

## Bank balances on April 2, 1956

Savings account in Fidelity-Philadelphia Trust Co. . .	\$3,472.20	
Checking account in Fidelity-Philadelphia Trust Co. . .	1,558.29	
		<u>\$5,030.49</u>

## Receipts:

Annual membership dues . . . . .	\$ 893.50	
Postage paid by foreign members . . . . .	13.00	
Sale of studies in Physical Anthropology . . . . .	12.00	
Interest of savings account . . . . .	31.83	
Transferred from previous Treasurer . . . . .	1,530.65	
Transferred from editorial account . . . . .	349.89	
Wenner-Gren Foundation publication grant . . . . .	3,000.00	
Redeposit of check charged back for correct endorsement . . . . .	2.00	
		<u>\$ 5,832.87</u>
		<u>\$10,863.36</u>

## Expenditures:

To Wistar Institute (subscriptions) . . . . .	\$ 449.00	
To Wistar Institute (program) . . . . .	88.42	
Addressing machine and accessories . . . . .	218.80	
Secretarial expenses . . . . .	157.49	
Foreign members mailing costs . . . . .	7.00	
U. S. Savings Bonds, Series J . . . . .	3,600.00	
Expenses, 25th annual meeting . . . . .	60.35	
Check returned for proper endorsement . . . . .	2.00	
Transferred to present Treasurer . . . . .	1,530.65	
		<u>\$ 6,113.71</u>

## Bank balance on April 1, 1957

Ann Arbor Bank, State Street Office . . . . .	4,749.65	
		<u>\$10,863.36</u>

*Investment Account:*

U. S. Savings Bonds, Series F, purchased June 9, 1949 (current redemption value \$1,696.00), maturity value . . . . .	\$2,000.00	
U. S. Savings Bonds, Series J, purchased May 8, 1956 (current redemption value \$3,620.00), maturity value . . . . .	5,000.00	
		<u>\$7,000.00</u>

*Audited and found to be correct*

April 13, 1957

F. CLARK HOWELL

E. CARL SENSENIG

*Auditing Committee*

*Respectfully submitted*  
J. N. SPUHLER, *Treasurer*  
April 2, 1957

In the absence of S. L. Washburn, the Report of the Editor was given by F. Clark Howell, Associate Editor. Manuscripts continue to be presented at a good rate. Editorial work requires about one month and papers are forwarded to the Wistar Institute approximately three months before their scheduled date of publication. There was considerable discussion of a 20 printed page limit on articles with authors having the option of paying for additional pages. The membership desires that the Editor should keep considerable freedom of choice in this matter. Compact writing and subsidies provided or arranged by the authors will help in many cases. It is recognized that some long articles cannot simply be divided without loss. There was general feeling that length alone should not disqualify a paper. Both the Editor and the Executive Committee recommend that the *Studies* series be continued should a suitable monographic manuscript become available.

William S. Laughlin reported on the 1st International Congress of Human Genetics held in Copenhagen, August 1956, and William W. Howells reported on the 5th International Congress of Anthropological and Ethnological Sciences held in Philadelphia, September 1-9, 1956. The proceedings of both congresses contain a number of papers of interest to physical anthropology and are to be published. A highlight of the Philadelphia Congress was the attendance of the delegation from the U. S. S. R., including a paper at the general session on physical anthropology by Dr. G. F. Debets on "Recent Developments in Physical Anthropology in the Soviet Union."

Russell W. Newman reported that the National Research Council Committee on Physical Anthropology is negotiating with the National Mail Order Association for a nation-wide anthropometric survey for size information to be conducted in the near future.

The report of the Constitution Committee was presented by W. W. Greulich. The Committee was appointed by President Trotter in 1955 with W. Montague Cobb as Chairman, and Harold Cummins, W. W. Greulich, G. W. Lasker, and M. T. Newman as members. Meetings of the Committee at Swamp-

scott in October 1955 and at Milwaukee in April 1956 resulted in suggestions for revision of the Constitution and By-laws as previously revised in 1940, 1943, and 1953. These revisions were approved by the Executive Committee meeting of April 5, 1956 and were presented by title to the membership during the business meeting of April 6, 1956. Additional revisions were made by the Committee in conjunction with the Executive Committees of 1956 and 1957. A final revision was approved by the Executive Committee on April 11, 1957. The revised Constitution and By-laws, presented below, were ratified by the membership on April 13, 1957.

---

## AMERICAN ASSOCIATION OF PHYSICAL ANTHROPOLOGISTS CONSTITUTION AND BY-LAWS

### *Preamble*

(See original Preamble as printed in AJPA, Volume 14, no. 2, 1930)

### CONSTITUTION

#### ARTICLE I. *Name and Purpose*

*Section 1. Name.* The name of this society is the American Association of Physical Anthropologists.

*Section 2. Purpose.* The purpose of the Association is the advancement of the science of physical anthropology.

#### ARTICLE II. *Officers*

*Section 1. Officers.* The officers of the Association shall be a President, a Vice President and a Secretary-Treasurer.

*Section 2. Terms.* The President and Vice President shall be elected for terms of two years each in alternate years. The Secretary-Treasurer shall be elected for a term of four years.

#### ARTICLE III. *Executive Committee*

*Section 1.* The management of the affairs of the Association in the interim of the meetings is delegated to the Executive Committee, which shall consist of six members, including the three officers.

*Section 2.* One member of the Executive Committee, exclusive of the officers of the Association, shall be elected annually to serve for three years.



ARTICLE IV. *Meetings*

*Section 1.* The Association shall meet once a year, except when special circumstances require otherwise, at a time and place to be determined by the Executive Committee.

ARTICLE V. *Membership*

*Section 1.* Membership shall be open to professional anthropologists, advanced graduate students showing evidence of professional capacity, professionals in cognate sciences, and others who have demonstrated qualification by publication or other professional activities.

ARTICLE VI. *Dues*

*Section 1.* There shall be annual dues in amount to be fixed by the Association at an annual meeting and duly incorporated into the By-laws of the Association. This shall include the amount of annual subscription to the American Journal of Physical Anthropology.

ARTICLE VII. *Amendment*

*Section 1.* Any change in the Constitution or By-laws of the Association must be proposed in writing by at least five members at one annual meeting. Such proposal shall be referred to the Executive Committee, and if approved will be presented for vote at the next annual meeting. A two-thirds vote of members present will be necessary for adoption.

ARTICLE VIII. *Publications*

*Section 1. Official Organ.* The official organ of the Association shall be the AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY.

*Section 2. Editor.* At proper intervals the Association shall nominate the Editor of the Journal to serve for a term of six years.

*Section 3. Editorial Board.* The Association shall nominate for the assistance of the Editor an editorial board of four Associate Editors, of whom one shall be nominated annually to serve for four years.

## BY-LAWS

CHAPTER I. *Nomination and Election of Officers*

*Section 1. Nominating Committee.* Regular nominations for office shall be made by the Nominating Committee, which shall consist of three members appointed annually by the President not less than three months before the annual meeting of the Association.

*Section 2. Duties of the Committee.* In its selection of members to be proposed for office, it shall be the duty of the Nominating Committee to endeavor to ascertain by mail poll the wishes of the membership. The Committee, however, is not bound by popular opinion but is charged with the exercise of its most mature and considered judgment.

*Section 3. Nominating Procedure.* At each annual meeting the Nominating Committee will submit a nomination or nominations for each office for which a term expires. The names of candidates so submitted shall be made known to the membership at least three weeks in advance of the annual meeting. Additional nominations for any office may be made from the floor if submitted in writing over the signature of five members.

*Section 4. Election.* Election shall be by written ballot at the annual meeting of the Association.

*Section 5. Terms.* All terms of office shall commence with the close of the annual business meeting at which election takes place.

## CHAPTER II. *Nomination and Election of Members*

*Section 1. Proposal.* Candidates for membership shall be proposed in writing with the endorsement of two members of the Association. The names of candidates must be submitted to the Secretary-Treasurer of the Association together with a statement of their qualifications.

*Section 2. Consideration.* At its regular meeting the Executive Committee shall consider all candidates duly proposed. Those approved shall be recommended for election by the Association at the business session of the ensuing annual meeting.

*Section 3. Election.* At the annual business session the Secretary-Treasurer shall present the list of candidates for membership approved by the Executive Committee. In the absence of objection from the floor to any name presented, the Secretary-Treasurer shall be instructed to cast a unanimous ballot for the list submitted. Any name challenged from the floor may be withdrawn upon proper motion for further consideration, provided the reason for the objection is stated. If the motion to withdraw a name is lost, the candidate shall be voted upon separately. A three-fourths vote of the members present shall be necessary for election.

## CHAPTER III. *Meetings*

*Section 1. Business Meeting.* One session of the annual meeting shall be devoted to the business affairs of the Association, including election of officers and members, reports of officers, committees and delegates, the finances of the Association and such other business as may properly be brought before it.

*Section 2. Quorum.* Forty members in good standing shall constitute a quorum at the annual business meeting.

*Section 3. Executive Committee.* The Executive Committee shall meet regularly just prior to the annual meeting of the Association and at such other times as the business of the Association may require. The session of the Executive Committee just prior to the annual meeting shall be called its regular meeting.

*Section 4. Agenda.* At its regular meeting the Executive Committee shall determine the agenda for the annual business session and the candidates for membership to be recommended for election.

CHAPTER IV. *Dues*

*Section 1. Amount.* The annual dues of the Association shall be \$2.00 plus the amount of the annual subscription rate to the American Journal of Physical Anthropology offered to members of the Association.

*Section 2. Voting Privilege.* Only members whose dues have been paid for a given year are considered in good standing for that year and entitled to vote in the annual business meeting. It shall be the duty of the Secretary-Treasurer to ensure proper compliance with this provision.

*Section 3. Delinquents.* A member in arrears of dues after two years shall be dropped automatically.

*Section 4. Reinstatement.* A member dropped from the rolls for non-payment of dues may be automatically restored to membership by the payment of dues in any subsequent year without reinstatement fee.

CHAPTER V. *Publications*

*Section 1. Editor.* At the regular expiration of term, the Executive Committee shall nominate the Editor of the American Journal of Physical Anthropology. This nomination, after approval by the Association at the annual business session, shall be forwarded to the Wistar Institute of Anatomy and Biology.

*Section 2. Associate Editors.* The Editor with the advice and consent of the Executive Committee, shall nominate each year one associate editor of the Journal for the approval of the Association at the annual business meeting. When approved by the Association, this associate editor shall be recommended to the Wistar Institute of Anatomy and Biology.

CHAPTER VI. *Vacancies*

*Section 1.* In the event of a vacancy in the office of President, the Vice President shall become President.

*Section 2.* The Executive Committee shall appoint a member in good standing to fill any vacancy among the Vice President, Secretary-Treasurer and Executive Committee. Such appointment shall hold until the next annual meeting when any unexpired term shall be filled by regular nomination and election procedure.

*Section 3.* In the case of a vacancy among the Editor and Associate Editors of the Journal, the Executive Committee shall be empowered to nominate to the Wistar Institute of Anatomy and Biology a member in good standing for the unexpired term of the place left vacant, subject to the approval of the Association at its next annual meeting.

---

William W. Howells outlined the present state of physical anthropology in Hungary and reported much loss of both collections and instruments in the anthropology section of the Hungarian National Museum. A resolution to contribute \$100 in support of physical anthropology in the Hungarian National

Museum was defeated on the grounds that the Association did not desire to make a contribution to an agency of the Hungarian government at this time. Considerable sentiment was expressed by members in favor of individual gifts or awards to physical anthropologists in Hungary.

The Association voted to discontinue the PA Newsletter in its present form. President Trotter appointed William J. L. Felts and Paul T. Baker as Co-chairmen of an Editorial Committee with responsibility for development of a Newsletter which would combine short notes on techniques and research as well as personal news.

The Association voted to co-sponsor appropriate sessions of the American Anthropological Association's 56th annual meeting in Chicago, December 27-30, 1957.

Gabriel W. Lasker called attention to the problem of scheduling national and regional anthropological meetings. In particular the Christmas meetings of Section H, AAAS and of the American Anthropological Association have competed with one another for attendance. The general policy of Spring meetings for the Association, set not to conflict with meetings of the Anatomists, had a majority approval of the membership in attendance.

The 27th Annual Meeting of the AAPA will be held in Cambridge, Massachusetts, on April 11-13, 1958 at the invitation of Harvard University. The scientific sessions and business meeting will be held in the Lamont Forum Room, Lamont Library, and the annual dinner will be served in the Harvard Faculty Club.

Dr. W. S. Laughlin reported for the Resolutions Committee:

#### RESOLUTIONS 1957

##### *Be it resolved:*

1. Be it resolved that the AAPA express its unreserved appreciation for the splendid accommodations and hospitality to the President of the University of Michigan, and to the Chairman of the Department of Anthropology and to the Chairman of the Department of Human Genetics. Special thanks are due for the excellent Supper Conference of April 12 made possible by the Wenner-Gren Foundation, and the fine lunch of April 13 provided by the University

of Michigan. Thanks are also due to the four faculty hosts at the University of Michigan who gave most enjoyable cocktail parties the afternoon of April 12. To the Program Committee and Local Arrangements Committee great appreciation is tendered for their excellent work in preparing these rewarding meetings. Appreciation is also expressed to Dean Albert Furstenberg, of the University of Michigan Medical School, and to Dean Charles Odegard, College of Literature, Science, and the Arts, for their welcoming addresses.

2. Be it resolved that appreciation be expressed to the Wistar Institute of Anatomy and Biology, and to the Wenner-Gren Foundation for Anthropological Research for their continued support of our science and of the Journal.

3. Be it resolved that condolences of the Association be sent to the families of Dr. Hubert S. Howe and Capt. Harry C. Meyers, Jr., U. S. Air Force.

*Respectfully submitted,*

WILLIAM S. LAUGHLIN

MARSHALL T. NEWMAN

The Chairman of the Nominating Committee announced the following candidates for office, whose election immediately followed the closing of nominations: President, Dr. W. Montague Cobb, to serve until 1959; Executive Committee member: Dr. W. W. Greulich, to serve until 1960.

The scientific part of the meeting included the papers listed below.

Papers contributed through the ASHG are listed by title as are those read in the Wenner-Gren Supper Conference on "Natural Selection in Man." The latter are to be published in full in the *American Anthropologist*.

1. *Skeletal maturation: an appraisal of concept and method*. Frank Falkner, Department of Pediatrics, University of Louisville.

During recent years it has been the practice to assess the maturity of the skeleton, clinically and in developmental studies. The discussion centers on usefulness of this procedure, its concept, and methods of its assessment. Growth, as increase in length of the human skeleton, occurs by proliferation of cartilage cells. After vascular penetration of primary and secondary centers, ossification occurs and when this has been completed, bone growth has ceased. Whether these two processes are in fact separate is discussed; although they may be intimately linked in health, dissociation may occur and their relative rates may differ. Examples of this dissociation are given including the effect of illness on the growing child. Past methods of assessment are reviewed and the great difficulties presented.

A newer technique, the Oxford Method, is described and figures showing a high correlation between independent observation of a series of films were presented.



Samples of children in Oxford, Paris, and London appeared to have similar skeletal maturation patterns in the first three years of life, while a sample from Dakar, West Africa, appeared to be advanced in the early days of life and the advance of the female over the male apparent in other samples was not found.

2. *Estimation of skeletal age from combined maturational activity.* Thomas W. McKern, Quartermaster Research and Development Command, Natick, Mass.

The successful calculation of the age at death from the observed maturational status of skeletonized remains is customarily based on as many growth areas as possible and final age assessments are in the form of mean averages. The justification for this process of combining many individual observations is founded on the assumption that the more events observed, the more accurate are the results.

Based on data collected on 450 skeletonized and identified U. S. war dead, 17 to 50 years of age, this paper tests the relative merits of five groups of skeletal age indicators. The following conclusions are presented:

1. Age estimations derived from the combined maturational activity of a few growth areas of the skeleton are just as reliable as estimations based on the total number of growth areas.

2. Smaller groups of skeletal growth areas are better age indicators only if they are made up of certain critical or key maturative events.

3. *Growth and skeletal maturation in malnourished Indian boys from the Peruvian Sierra.* Marshall T. Newman and Carlos Collazos Ch., Division of Physical Anthropology, U. S. National Museum, Washington, D. C., and Departamento de Nutricion, Ministerio de Salud Publica, Lima, Peru.

The population studied is a largely inbreeding community of 1800 Quechua Indian farmers living on 36,000 acre Hacienda Vicos, 10-12,000 feet high in the North Central Sierra. Contrasting with other Sierra series, over 200 Vicos boys show a mean deceleration in growth, especially stature and weight, from about 10-15 years of age. This deceleration is also evident in sitting height, arm length, biacromial breadth, calf circumference, and bizygomatic breadth. In 100 x  $\frac{\text{weight}}{\text{stature}}$ , Vicos boys show a consistent mean weight depression in 10-15 year-old. Plotted against skeletal age, the growth deceleration is even more marked than by chronological age. In skeletal age, Vicos boys average 2 years, 9 months behind Greulich-Pyle standards, much more than in coastal mestizos. Dr. Harald Schraer found no increase in bone mineralization from 7-17 years in 91 Vicos boys, whereas U. S. whites show a 50% increase in this period.

Provisionally the decelerated growth pattern, low bone mineralization from 13 years on and slow skeletal maturation may be considered adaptations to dietary inadequacies and intestinal parasite infestation grave even for the Sierra. Average food intake from three surveys was 14, 6 and 60%, respectively, of adjusted INCAP recommendations for calcium, vitamins A and B-2. Clinical examinations of 121 boys revealed widespread, mostly mild signs of vitamin deficiencies, referable largely to lack of A and B-2. Eighty-two per cent of 200 Vicos Indians had ascaris with other debilitating intestinal parasites running almost that high. After three years of vitamin and mineral therapy, a restudy of the Vicos subadults is planned for the purpose of more directly relating inadequate nutrition to physical and clinical status.

4. *The estimation of dry skeletal weight from roentgenographs of the femur and humerus.* Paul T. Baker and Harald Schraer, Quartermaster Research and Development Center, Natick, and The Bone Density Evaluation Center, Pennsylvania State University.

In an effort to improve measurements of human body composition, a method is being developed for predicting the dry skeletal weight of young men from roentgenographs of their upper arm and thigh. The basic data were obtained from the dry bone weights and X-ray plates made on 81 White and 19 Negro skeletons. Because the Negro skeletons had significantly different bone weights than the Whites, it was deemed necessary to analyze the results separately. In the White group the femur and humerus weights have a multiple correlation value of .93 to total skeletal weight.

The X-ray plates were made with a densitometric wedge. This permits the measurement of bone mass or density when the films are processed with the bone density computing machine. It was found that bone mass as computed from the X-ray plate was a good predictor of dry bone weight, and that there was a multiple correlation of .86 between the femur and humerus mid-shaft mass and total dry skeletal weight. These values were developed using only dry bone; consequently a correction factor for the soft tissue in and around the bone must be developed before the technique can be applied to the living. These corrections will probably be developed within the next year, making available for general use a reasonably accurate method for assessing the dry bone and ashed bone weight in young men.

5. *Transplantation as a technique in the study of skeletal organogenesis.*<sup>1</sup> William J. L. Felts, Department of Anatomy, University of Minnesota.

The author will illustrate how subcutaneous implants of immature postnatal long bones (rats and inbred mice) have been used to study development of skeletal organs in the absence of normal functional circumstances. From experiments of short and long duration, with immediate and delayed implantation of whole or segmented postnatal bones, certain comparisons will be made with the work of Fell and others who have demonstrated the relative autonomy of embryonic skeletal development. Our major conclusion is that, given minimum optimal conditions of vascularity, the cartilage masses of the postembryonic long bone are capable of organotypic development in the absence of functional circumstances. This is true whether or not the cartilage is in normal relationship with the other tissues of the organ. In both the paper from the platform and the demonstration, it will be shown that such implants are also valuable test objects for studies of tissue survival in storage and of the immune reaction to skeletal tissue transplants. At the present time a study is being made of the growth response of whole bones implanted within plastic and steel spring rings of graded strength. Preliminary results of this experiment will be presented.

<sup>1</sup> This work is supported by grants from the National Institute of Arthritis and Metabolic Diseases (A-1104) and the Graduate School, University of Minnesota.

6. *A comparison of the techniques used in the study of prenatal ossification.*<sup>1</sup>

Ronan O'Rahilly and David B. Meyer, Department of Anatomy, Wayne State University.

The human skeleton, during the first half of prenatal life, is studied at present by three chief methods: Clearing of fetuses followed by staining with alizarin red S, radiography, histological sectioning. In the present investigation the hands and feet of several fetuses have been studied by employing all three methods on the one specimen. In each case one half of the body was cleared and stained with alizarin red, whereas the other half was impregnated with silver and radiographed. Subsequently the hand and foot from this latter moiety were sectioned and stained with a polychrome stain. The histological control has made possible a detailed assessment of the relationship of the results of the two macroscopic techniques to the initial onset of ossification in the various skeletal elements.

---

<sup>1</sup> Supported by grant A-532 from the National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, U. S. Public Health Service.

7. *Rate of development of vertebral hypertrophic arthritis and its utility in age estimation.* T. D. Stewart, U. S. National Museum, Washington, D. C.

At the 16th Annual meeting of this association I read a paper on "Racial patterns in vertebral osteoarthritis" (Am. J. Phys. Anthropol., n.s., vol. 5, no. 2, June 1947, appendix pp. 6-7). The emphasis there was on intensity of involvement of the individual spinal segments and its relationship to degree of joint motion. Included in that study was a group of 104 whites of known age from the Terry Collection in St. Louis. However, only incidental mention was made of the fact that whites under 55 years of age have less vertebral lipping than those over 55.

In the present study the St. Louis males (87) have been combined with 367 American soldiers killed in Korea to show the rate of development of vertebral lipping between the ages of 17 and 84.

The findings have an important bearing on the estimation of age from the skeleton. After closure of the epiphyses the best indication of age is yielded by the symphyseal surface of the pubis. When this part is damaged or missing the only age indicators left are suture closure, dental deterioration and joint lipping. Of these three the first two are quite unreliable and the third has not been used widely because of lack of information about its rate and regularity of development. The evidence to be presented shows that vertebral lipping develops fairly regularly, especially after 40, and hence is useful in identifying the older age groups. Under 30, lipping is seen only occasionally in modern whites and appears to be associated with injuries to the back.

8. *Incidence of osteophytosis and osteoarthritis in 419 skeletonized vertebral columns.* Maurice B. Roche, Department of Orthopedic Surgery, Saint Louis University.

A series from the Terry Skeleton Collection of 419 vertebral columns of American whites and Negroes of both sexes, ranging from 20 to 99 years, was examined for the presence of osteophytosis (lipping of vertebral bodies) and osteoarthritis

involving the joints between the articular processes of the vertebrae. It was found that:

1. The incidence of osteophytosis is higher than of osteoarthritis.
2. The incidence of both are slightly higher in whites than in Negroes, in older skeletons than in younger skeletons, and in females than in males. However, with increasing age, the incidence in the males equals or exceeds that found in the females.
3. In all but 3% of columns having osteoarthritis, osteophytosis was present as well; whereas, 25% of columns with osteophytosis showed no evidence of osteoarthritis. The degree of osteophytosis in this 25% was less than in columns which presented osteoarthritis as well.
4. On the basis of this evidence, it is suggested that, with osteophytosis appearing earlier and followed by osteoarthritis, the two conditions may have a causal relationship; and that the presence of osteophytes of the vertebral bodies may be necessary to the presence of osteoarthritis of the articular processes.

9. *Sex differences in the circumaricular area of the human ilium.* Lucile E. Hoyme, U. S. National Museum, Washington, D. C.

The posterior part of the human innominate shows a number of details which are useful as criteria for assessing sex. The majority of these features are either in the sacroiliac joint itself or in the areas immediately adjacent to it. This suggests that the observed features are not independent of each other, but are, rather, expressions of a few fundamental sex differences.

Two of these fundamental sex differences in the posterior pelvis can account for the majority of the morphological details observed. These are the longer ilium found in females and the different function of the sacroiliac joint in the two sexes.

Observation on innominates of children, adolescents and adults indicate that growth at the auricular surface takes place both backward from the sciatic notch and inward toward the midline. The greater backward growth in females tends to elongate the iliac blade and widen the sciatic notch. Individual variation in the resorption of the juvenile border of the sciatic notch as the auricular surface is displaced backward accounts for both the preauricular sulcus and the various bony spurs projecting into the notch. Growth inward elevates the auricular surface above the surrounding bone, accounting for other structural differences seen. Sex differences in joint function account for other details, including the differences in size and form of the auricular surface and the morphology of the post-auricular area.

10. *Xeroderma pigmentosum and partial sex-linkage.* Herluf H. Strandkov and Robert E. Hostetter, Department of Zoology, University of Chicago.

11. *Genetic factors in allergic diseases.* Robert L. Tips and C. Wallace McNutt, Departments of Internal Medicine, Bacteriology, and Anatomy, University of Texas Medical Branch, Galveston.

12. *The physiological defect and mode of inheritance of vitamin-D resistant rickets in a large North Carolina kindred.* John B. Graham and others, Department of Pathology, University of North Carolina.

13. *The genetic eligibility of donors who serve for the purpose of artificial insemination.* W. T. Pommerenke, Department of Obstetrics and Gynecology, University of Rochester.

14. *Frequency of genetic transmission of sporadic retinoblastoma.* Donald P. Tucker, Arthur G. Steinberg, and David G. Cogan, Harvard Medical School, and Department of Biology, Western Reserve University.

15. *Inheritance of gall bladder disease.* Charles E. Jackson and Brian C. Gay, Caylor-Nickel Clinie, Bluffton, Indiana.

16. *Genetics of human cancer in children and adults.* Sigismund Peller, 164 East 81st Street, New York 28, N. Y.

17. *The detection of possible carriers in hereditary myoclonic epilepsy.* Bruce Sarlin, H. Warner Kloepper, Walter Mickle, and Robert G. Heath, Tulane University.

18. *Familial aspects of cerebral palsy.* Irene Uchida, Hospital for Sick Children, Toronto, Ontario.

19. *Some possibilities for measuring selection intensities in man.* James F. Crow, Department of Genetics, University of Wisconsin.

20. *The influence of the ABO system on Rh hemolytic disease.* Philip Levine, Ortho Research Foundation.

21. *Selection for morphological characters in man.* Carleton S. Coon, University Museum, University of Pennsylvania.

22. *The study of natural selection in primitive and civilized human populations.* James V. Neel, Department of Human Genetics, University of Michigan.

23. *The main variations of external body form.* W. W. Howells, Department of Anthropology, Harvard University. Abstract not submitted.



24. *Constitutional studies and scientific methodology.* Marvin J. Schwarz, Irvin Emanuel and James T. Barter, Institute for Juvenile Research, Chicago, University of Rochester Medical School, and Anthropology Section, Air Force Aero-Medical Laboratory.

The Sheldonian system of physique typology, Somatotyping, has been widely accepted by physicians, psychologists, and others interested in means of relating human biology to the non-physiological aspects of the individual. When the system and its applications are critically evaluated, major inconsistencies, false assumptions, and misapplications of scientific methodology are noted.

The statistical formulations used to validate the technique of body typing are evaluated and found to be contrary to accepted scientific procedures. The use of the correlation coefficient as a measure of interobserver reliability is seriously questioned. Anthroposcopic dysplasia ratings do not correlate with morphological variability as determined by anthropometry.

A review of the application of somatotyping methods in clinical medicine, occupational proclivity, and psychiatry show that the statistical treatment of the relationships fail to support the conclusions. Errors in sampling technique, misapplication and misinterpretation of the meanings of the correlation coefficient, and the failure to use adequate tests of significance are pointed out. This has tended to weaken the hypothesis that body form is in any way related to non-biologic characteristics of the individual.

25. *Variation in discrete traits between Greenlandic Eskimo cranial isolates.* W. S. Laughlin, University of Wisconsin and J. B. Jørgensen, University of Copenhagen.

Six hundred Eskimo crania in the Laboratory of Anthropology, University of Copenhagen, were studied with particular attention to the presence or absence of eight discontinuous traits: dehiscences and marginal foramina of the tympanic plate, parietal notch bone, direction of the superior sagittal sinus, supraorbital foramina, mylo-hyoid arch of the mandible, mandibular torus and palatine torus. Two major aims of this study were (1) determination of the feasibility of employing discrete traits, in addition to metrical measurements, in studies of skeletal isolates and (2) determination of the direction of Eskimo migration around the coasts of Greenland. The crania were grouped according to their origin in the four isolates of varying distance and definition: Northwest, Southwest, Southeast and Northeast Greenland. The biological distance between these four isolates was estimated by means of the coefficient for distance, size and shape of L. S. Penrose. Owing to the Inland Ice all Eskimo migrations have been confined to linear movements about the coasts with no gene exchange possible across the island, thus, only three possibilities existed. The Eskimos could migrate clockwise, counterclockwise or in both directions. The recurrent question of the origin of the Angmagssalik Eskimos of Southeast Greenland epitomizes the problem of migration direction. If they had come south along the west coast, turned about the southern tip of Greenland and moved north along the East coast to their present position, they might be expected to show the largest degree of difference from the Eskimos of the Northeast coast who presumably came around the northern end of Greenland and migrated

southward along the East coast, and to show lesser degrees of distance from the more closely related isolates along their route. The results of this study yield the largest difference between these two east coast isolates, thereby indicating that they did arrive at their final positions from opposing directions. The distinctiveness of the Northeast isolate suggests that they may have separated from the other Greenland Eskimos before arriving in Greenland. The frequencies of these discrete traits is presented for males and females of the four isolates. The frequencies for one hundred three mediaeval Norse crania from Southwest Greenland are also presented.

26. *Exogamy and heterosis.* Frederick S. Hulse, Department of Anthropology, University of Washington.

Despite cultural rules favoring exogamy, most human communities of the past have been rather endogamous. For many reasons this is becoming less and less true. It has been suggested that migrants especially are likely to marry outside their ancestral community. It has been observed that the offspring of migrants are usually larger than their parents. Better living conditions are often alleged to be the cause of this greater growth. Another hypothesis, however, has been that this greater growth is due to heterosis, or hybrid vigor, because of the exogamy of the parents.

To test this hypothesis, I compared the offspring of intra-village marriages with the offspring of extra-village marriages, in a series of several hundred males from the Canton of Ticino, in Switzerland, and in 100 California-born sons of migrants. Offspring of village exogamous marriages average more than 2 cm. taller than offspring of endogamous marriages, in both series. However, the California-born are 4 cm. taller than the Swiss-born.

Other measures of growth are presented, together with some observed characteristics. There is little suggestion of any basic genetic difference between endogamous and exogamous, Swiss-born or California-born. Consequently the observed differences in size can best be explained as due to heterosis in Switzerland, and to the combination of heterosis and better living conditions in California.

27. *The distribution of the sickle cell gene in Liberia.* Frank B. Livingstone, Department of Human Genetics, University of Michigan, Ann Arbor, Michigan.

Data are presented on the distribution of the frequency of the sickle cell trait in Liberia. Among the native tribes of Liberia the frequency varies from 0 to 20%. There is a northwest-southeast cline in the frequency with the tribes in the northwest half of Liberia having 12-20% and the tribes in the interior of southeast Liberia having 0%. This cline continues to the northwest into Sierra Leone where the tribes have about 30% of the sickle cell trait.

Since Liberia is throughout a highly malarious country, the data are not in agreement with Allison's malaria hypothesis. This hypothesis explains the high frequencies of the sickle cell trait by a balanced polymorphism in which the sickle cell trait carrier has a relative immunity to falciparum malaria and hence a selective advantage in regions where falciparum malaria is holoendemic. This selective advantage of the heterozygote for the sickle cell gene then offsets the selection against the gene due to the early death of the homozygotes.

The disagreement between the malaria hypothesis and the distribution of the sickle cell trait in Liberia seems to be due to the fact that the gene has recently been introduced into Liberia and is only now spreading through the country.

28. *The Negro of Charleston, South Carolina; a study of morphology, serology, and hemoglobin varieties.* William S. Pollitzer, Institute for the Study of Human Variation, Columbia University.

Data are presented on approximately 500 Gullah Negroes. Comparisons are made with natives of West Africa, general American Negroes, and whites. Values for abnormal hemoglobin in the Charleston sample are close to African figures, and may have been maintained at this high level through the action of falciparum malaria. The degree of similarity between the Negroes of Charleston and the other populations has been analyzed by two methods: Chi-square of the gene frequencies for blood types, and the generalized distance of Mahalanobis for the morphological traits. Results of both methods are similar and show that the Charleston Negro is distinct from, and closer to Africans than, the general American Negro. Hybridization to a lower degree, and possibly involving different ancestral stocks, is advanced as the major cause of the biological position noted.

29. *Racial variations in serum haptoglobins.* H. Eldon Sutton, Department of Human Genetics, University of Michigan.

The technique of serum electrophoresis in a low ionic strength starch gel as developed by Smithies reveals the presence in human beings of qualitative differences in the haptoglobins. These differences are under genetic control, resulting from a two-allele system lacking dominance. Studies conducted in this laboratory on different racial groups show the following gene frequencies for the Hp<sup>1</sup> allele: Caucasian, .42; Apache, .52; American Negro, .72; and African, .71. The importance of selection on this system will be discussed.

30. *Physiological observations on the Ramah Navaho.* Gordon Allen and J. N. Spuhler, Laboratory of Socio-environmental Studies, National Institute of Mental Health, and Departments of Anthropology and Human Genetics, University of Michigan.

Near-basal systolic blood pressures of Navaho Indians are significantly below reported blood pressures of Puerto Ricans and white industrial workers. However, the initial readings for the Navaho, which may be more nearly comparable, approach the blood pressures of whites and generally exceed those of the Puerto Ricans. By either criterion, the Navaho differ from the other two groups by the virtual absence of a blood-pressure rise with age in the females.

Blood pressure, pulse, cold pressor response and Schneider Physical Fitness Score are all significantly related to age, as are weight and somatotype. Schneider Score is significantly higher in the older individuals, and in the most acculturated males despite their younger average age.

Family analysis suggests that genetic factors largely determine blood pressure in the Navaho. These factors seem to be rather sex-specific and therefore different from those acting at the higher blood pressure levels studied genetically in whites.

31. *Bio and cultural genetics.* Burt Aginsky, Department of Anthropology, City College, New York. *Read by title.*

32. *Tri-racial isolates of Eastern United States.* Calvin L. Beale, United States Department of Agriculture.

There are many communities of people of mixed racial ancestry that form distinct racial or social isolates in the Eastern United States. The great majority of these are, either in fact or by tradition, of tri-racial origin—Indian, Negro, and white.

Such isolates apparently formed through miscengenation in the Colonial and early Federal periods. The offspring tended to marry among themselves, being barred from white society and spurning Negro unions. The result is the persistence of numerous groups of such racial hybrids today, with a background of high rates of consanguineous marriage.

An inspection of the records of the 1950 Census of Population was made to estimate the size of these groups and to determine their location and racial status. Seventy-seven thousand persons were identified in 16 States, omitting several ill-defined groups and those living in cities. Thirty-three thousand were enumerated as Indian, 29,000 as white, 14,000 as Negro, and 1,000 as other races or without a race entry.

The tri-racial communities have come to the attention of a few cultural anthropologists, but seem never to have been mentioned in the annals of physical anthropology or, until 1955, human genetics. From their peculiar racial composition and long history of inbreeding they merit the attention of both of these sciences.

33. *Genetic study of a tri-racial isolate in Maryland.* Carl J. Witkop, Jr., National Institute of Dental Research, National Institutes of Health, Public Health Service, U. S. Department of Health, Education and Welfare, Bethesda, Maryland.

A progress report on the Brandywine Study reveals at this time that at least 8% of this population has serious hereditary disease. Two conditions, dentinogenesis imperfecta (153 affected individuals living) and total albinism (47 affected individuals living), account for about 4% of those affected. The gene frequency for albinism is probably from .0917 to .1010 in this population. A rare form of generalized hyperostotic bone disease with leontiasis has been studied in five affected members of this group. Several members of the group with sickle-cell disease have lived to reproduce offspring. Analysis of 317 marriages by family A males over a 104 year period shows that they married within the group 92% of the time. Of these marriages, 42% were to family A females and 20% were to family B females. Seventeen percent of these marriages were given dispensation for relationship within the first three degrees of consanguinity. Analysis of blood data shows the following distributions in about 200 samples.

Gene Frequency		Gene Frequency	
M	40.78	Fy <sup>a+</sup>	18.7
N	59.21	Fy <sup>a-</sup>	81.3 (neg. to Anti Fy <sup>a</sup> )
A	15.4	cDe	48.30
B	9.3	cDE	3.04
O	75.3	CDe	48.03
K+	0.0	CDE	0.63
K—	100.00 (neg. to Anti K)		

34. *The dentition of the Jarmo inhabitants.* A. A. Dahlberg, Zoller Memorial Dental Clinic and Department of Anthropology, University of Chicago.

Genetic and nongenetic dental features of the inhabitants of the early agriculturists of Jarmo, Iraq, reveal a dentition of moderately small teeth having characteristics seen in modern Mediterranean and European peoples. No mongoloid traits were noted in any of the 96 permanent and 30 deciduous teeth from the six individuals represented. There was no irregularity in tooth alignment nor any prognathism. Taurodontism was present in some molars, but was not extreme. Small modified Carabelli's cusps were present in two individuals and pits in the others. No protostylids were present. Hypocones on second and third upper molars were markedly reduced. Shovel-shaped incisor form was minimal, represented by definitely accented marginal ridges, but of such small proportion that classification would be in the category of "absenec." Unworn teeth showed tendencies towards crenated surfaces. Extreme wear on occlusal and proximal surfaces indicated heavy function. No marginal fractures were present that would suggest gross coarse substances in the diet. A prominent chin with generally slight build of bony structure was evident in the group.

35. *The races of Burma.* Lawrence Oschinsky, Department of Anatomy, Howard University.

Von Eickstedt ('44) has stated that the racial composition of Burma in particular and Southeast Asia in general contains Negrito (pygmy) and Veddo elements and has maintained that these groups were the original inhabitants of the area. He believes that they were driven out and partially absorbed by an unspecialized Mongoloid type (Palaeomongoloid, Neside) represented by the Mons or Talaings in Burma; the Khmer (Cambodians) and Moi of French Indo-China; and the Lawa of Siam. Montandon ('28, '33) on the other hand, indicates that Melanoid and Indoid elements are also visible.

In 1954-55 I had the opportunity to go to Burma on a Fulbright grant to do a somatometric-morphological survey of 14 Burmese groups including the Burmans proper, the Mons, Karens, Shans, Arakanese, Chins, and Kachins, for the purpose of investigating the racial taxonomic status of the Burmans. The problem was, are they more or are they less Mongoloid than has been maintained? Among the most useful of morphological characteristics in the study of Mongoloid populations in Southeast Asia is the epicanthic fold. The tribal distribution of this character in Burma, Siam, and Northeast India is as follows:

Burmans	72%	Fukienese	90%	Sino-Burmans	81%
Mons	60%	Bhotia (Bowles)	65%	Central Thai	
Karens	59%	Medium Indo-		(Andrews)	79%
Shans	84%	Burmans	62%	West Lao	
Tamils	0%	Dark Indo-		(Andrews)	87%
Arakanese	63%	Burmans	65%	Cantonese	100%
Kachins	85%	Light Indo-		Bhotia (Tiwari)	89%
Chins	81%	Burmans	59%		

Therefore, the Cantonese and the Fukienese are the most Mongoloid, and the Karens, Mons, Arakanese, and the Bhotia, the least Mongoloid for this character. No group drops lower than 59% for this character.



In skin color the lightest are the two Chinese groups, Shans and Sino-Burmans, and the darkest are the Tamils, Chins, Arakanese, and Dark Indo-Burmans.

In weight the groups vary from 107 lbs. for the light Indo-Burmans to 118 lbs. for the Karens, while the Burmese occupied an intermediate weight position of 112 lbs. The range in stature is from 161 centimeters for the Chins to 168 centimeters for the Fukienese. The Burmans measure 163 centimeters. For 20 body characters and 9 head characters the T test showed significant differences between the Burmans and the Chins; the Tamils showed 6 in the body and 12 in the head, and the Fukienese showed 10 in the body and 3 in the head.

The Chinese and the Chins have the shortest relative upper and lower extremity lengths. The Tamils have the longest extremities while the Burmans and other Delta groups are intermediate. The Cephalic index of the Burmans is 83.76, the intertribal range being Tamils 76.39 and the Fukienese being 86.18. The T test showed significant difference between the Burmans and 8 tribes for this character. Face index is less variable intertribally and Nasal index much less variable.

The ABO blood groups are of little racial taxonomic value since such distinct groups as the Chinese, Burmans, and Madrasis have similar gene distributions.

On the basis of the somatometric analysis, there are two main somatic groups in Burma. The first is the Chin-Kachin-Naga Hill group with relatively long trunks, short extremities, short stature, a high percentage of epicanthic folds and mesocephaly. The second of the Delta group includes the Burmans, Mons, Karens, and Arakanese with relatively shorter trunks, longer extremities, taller stature, a lower percentage of epicanthic fold, and low brachycephaly.

All groups except the Tamils varied little in hair form, hair color, eye color, nasal index, facial index, and lip thickness. Both groups resembled the Southern Chinese of Canton and Fukien more than the North or South Indian peoples. No traces of Negrito or Veddoid biological influences were found.

36. *Spectrophotometric study of pigments from human hair of various colors.*  
Bertram L. Hanna, Medical College of Virginia, Richmond.

Pigments from the hair of 94 individuals were extracted with dilute base and the absorption curves of the solutions in the visible light band were obtained. The regression of the logarithms of optical density on wave length was estimated for each of 11 hair colors and for 6 samples of auto-oxidized dopa-melanin. The results may be summarized as follows: (1) Previously reported findings of greater total pigment concentration and greater variation in concentration in dark hair colors are confirmed; (2) the regression of the logarithms of optical density on wave length is not dependent upon pigment concentration; (3) the slopes of the regression lines of dark hair colors are generally less than that of dopa-melanin and those of light hair colors are greater; (4) the variation in slope is independent of the slope of the regression line and of pigment concentration and is not related to the degree to which the slope deviates from that of dopa-melanin, and (5) the relative variation of the slopes of gray-black color shades is greater than that of yellow-brown shades. The results indicate that different human hair colors do not result from qualitative differences in pigmentation alone nor from differences in concentration of a single pigment. Observed color differences may result either from differing relative concentrations of two or more pigments or from relative differences in the size and refractive indices of pigment granules.

37. *The unreliability of blood typing aged bone.* Fred P. Thieme and C. M. Otten, Department of Anthropology, University of Michigan.

Vertebrae of 19 individuals of known blood type, secured from autopsy and aged in sandy soil over two years, were tested for blood type by the absorption method of Boyd and Candela in order to test the accuracy of the procedure. Three separate testings on each revealed a consistent error in 9 specimens while 10 tested accurately. Of the 9 in error, 8 were read as "O," since in the absorption-inhibition test failure to absorb either anti-A or anti-B is read as "O." Probably these antigens had been destroyed as well as some of the original "O" antigens.

The appearance of the vertebrae upon exhumation presented a wide variety of colors, textures and odors, ascribable to varying bacterial action. Workers for over two decades have shown that certain (now over 12) bacterial enzymes can decompose human blood group antigens as well as structurally related substances. Most of these bacteria occur in soil, in fecal material, and/or decaying animal tissue; they are, in general, at least facultative anaerobes and sacchrolytic in action. Thus they are ideal candidates to account for the observed antigenic destruction.

The enzyme of *Clostridium perfringens* (Welchii) was observed in its action on purified blood group antigens, secretor saliva and erythrocytes. The selective destruction of "A" antigen was verified. In addition, stains prepared from blood of known type which had been dried fresh on filter paper tested accurately after 9 months. However, blood allowed to putrefy in open tubes before drying gave readings 37% in error after 3 weeks and 53% in error after 8 weeks. When a half-gram of polluted soil was added to each tube of fresh blood, the mixture after 2 weeks at room temperature gave entirely erroneous reading. The same test methods were used on all the various samples.

The erroneous results obtained, using various treatments and aging, are probably due to the destructive action of bacterial enzymes although the absorption-inhibition test may itself be contributing to the error. In any event, we conclude that standard procedures cannot be relied upon to accurately reveal the blood type during life in aged decayed tissues.

38. *A comparison of the dermal configurations of Negro mongoloid imbeciles with those of other racial groups.* Norma Ford Walker and Elizabeth Doidge, Hospital for Sick Children, Toronto.

39a. *Considerations on synodontia.* Theodore E. DeJonge, Anatomical and Anthropobiological Department, University of Amsterdam (Holland).

I. In discussing geminate tooth formations, distinction may be made between schizodontia and synodontia—distinction which also expresses their twofold origin.

II. Schizodontia is a term applied to geminate teeth which originate in a division of a tooth anlage into a medial and a distal component.

They are morphologically progressive, manifested in the permanent series predominantly among the frontal teeth of the maxilla; the frequency in the mandible is considerably lower.

Schizodontia reaches its terminal phase with the development of two completely separate teeth, i.e. the geminate tooth has been replaced by two teeth. Their number is considerably smaller in the decidual dentition; here too, there is the same difference in frequency between the maxilla and the mandible.

Conclusion: schizogenous geminate teeth are extremely rare in the decidual dentition, particularly in the mandible.

III. Synodontia is a condition of pathological development. Its genesis is completely in contrast with that of schizodontia. It is based on complete or partial inability of two adjacent tooth germs to retain their individuality.

Synodontal geminate teeth, particularly when among the incisors of the mandible, may show an extreme degree of isomorphia with corresponding cases of schizodontia. Yet their behavior is completely in contrast with that of the last type; they develop primarily among the frontal teeth of the decidual dentition but to a much lesser degree among the permanent frontal teeth. The rarest form of synodontia is indubitably that affecting the permanent lateral incisor and the cuspid.

39b. *An analysis of the premolarization of the third upper molar.* Theodore E. DeJonge, Anatomical and Anthropobiological Department, University of Amsterdam (Holland).

Premolarization of the crown of the third upper molar can be based on reduction to such an extent that only the two anterior cuspids prove to be present in anlage. The remaining cuspids are lacking and the crown therefore shows the same anterodistal flattening that is seen in the premolars of the upper jaw. The crown formula is then  $\frac{P}{D}$ .

A second type may be described as a morphological mixtum compositum based on a crown form which, as a result of progressive simplification of structure, is tricuspid in nature. Its premolariformity is based on the independent manifestation of a superfluous mesiobuccal marginal tuberculum in front of the crown cuspid of the same name, and on the other hand on reduction of the distobuccal cuspid. The crown formula may then be written  $\frac{1 PaPp}{D}$ .

In a third group there is the same threefold structure of the buccal crown segment. The lingual segment, however, is still developed so as to show a virtually complete lack of the premolariform flattening which the above two groups have in common. In this case the crown formula is as a rule also  $\frac{1 PaPp}{D}$ . Only in a minority of cases would it be possible to write it  $\frac{1 PaPp}{D4(r)}$ .

40. *Serology, genetics and nomenclature of the Rh-Hr blood types.* Alexander S. Wiener, Office of the Chief Medical Examiner of the City of New York.

41. *The completed reproductive performance of 161 couples selected before marriage and classified by ABO blood groups.* T. E. Reed, Department of Human Genetics, University of Michigan.

42. *Blood donor controls for blood group-disease researches.* J. A. Buckwalter and R. T. Tidrick, University of Iowa Hospitals.

43. *The ABO blood groups in a large sample of hospital admissions in relation to the problem of natural selection.* John Buettner-Janusch, Department of Anthropology, University of Michigan.

Despite frequent suggestions for over fifty years that morbid conditions are related to the ABO phenotypes of individuals, general interest in disease as a mode of selection upon the ABO system is recent. The assumption that the ABO phenotypes are neutral to forces of selection affected the kinds of analyses attempted and the manner in which samples were collected. The literature reporting the ABO frequencies contains few examples in which healthy individuals are compared with the sick, or in which age, sex or other conditions are examined for significant differences.

A report of the distribution of the ABO frequencies in a sample of 7747 hospital patients is presented. The sample was selected by recording the blood groups of transfused patients admitted to University Hospital, Ann Arbor, Michigan between 1 January 1952 and 31 December 1953. When the patients were classified by age groups significant differences in the distribution of the ABO blood groups were found. The frequency of blood group O was elevated in the age group 21-30 years, and group A was elevated in the 1-10 years age group. A classification by age and sex demonstrated that the significant differences occurred only among males.

Comparison of the sample against healthy blood donors revealed significant differences in ABO distributions. Such comparisons with healthy donors raise questions about the proper choice of samples and controls. These questions are discussed.

44. *Anthropologic and genetic aspects of nanocephalic dwarfism.* H. P. G. Seckel, University of Chicago School of Medicine.

45. *Genetic factors in obesity.* J. Lawrence Angel, the Daniel Baugh Institute of Anatomy of the Jefferson Medical College, Philadelphia.<sup>1</sup>

In other mammals a recessive gene produces diabetic obesity and dominant genes produce hyperphagia and also yellow pigmentation, trunk elongation and homozygous lethal effect. In man psychological effects (of stress?) on hypothalamic activity versus social pressures combine with unclear definitions of obesity (e.g.  $ht/\sqrt{wt}$  below 12.0) to hide obese genotypes.

738 siblings of 135 white and 66 colored obese propositae spring from fat x fat (33%), fat x thin (53%), and thin x thin (14%) matings. Fat x thin data fit any hypothesis of a single dominant gene; unlikely penetrance differences or two

dominants with lethal effects might explain frequencies of obese among the sibs (56%, 41% and 22% for fat, mixed, and *thin* matings), the usual 3:1 female: male ratio stated for obese (here 71% of mothers and 48% of fathers are fat) and excess of sons in the fat x fat matings. Excess of fat daughters occurs only in thin x thin and fat male x thin female matings. Among whites only fat fathers have smaller families. Fat offspring of fat mothers have significantly raised serum cholesterol and thin x thin offspring lowered blood sugar and few diabetic relatives. Excess of green irides and of bloodgroup B is typical of white obese as a whole. Since human obesity may have overlapping environmental, social, and genetic causes it is not yet possible to disentangle all these factors.

---

<sup>1</sup> Supported by N.I.H. Grant A-224 and continuations.

46. *Innate abilities: one or many?* Steven G. Vandenberg, Hereditary Abilities Study, University of Michigan.

47. *A tentative explanation of the high incidence of diabetes mellitus.* R. H. Post, Institute for the Study of Human Variation, Columbia University.

The rapid growth and early sexual maturity reported for diabetics suggests that homozygotes for the recessive gene assumed to produce most cases of the disease may have superior procreative value, thus explaining high gene frequencies despite negative selection formerly operating. Data are presented suggesting that mean menarchial age of girls with post-adolescent onset of diabetes (presumably homozygotes) may be earlier than that of non-diabetic controls. Abstracted data are presented suggesting (1) earlier menarchial age may be associated with earlier age at first pregnancy among diabetic mothers, (2) mean family size of diabetic parents may be larger than that of non-diabetic parents.

48. *Creative anthropology: a cross discipline strategy for comprehensive research in human environment.* F. D. Van Wart, C. A. Dempsey, and John Duddy, Aero-Medical Laboratory, Wright Air Development Center. *Read by title.*

49. *Applied anthropometry of the foot.* Robert M. White, Quartermaster Research and Development Center, Natick, Massachusetts.

One aspect of military research and development in the Quartermaster Corps is concerned with the anthropometry of the foot and the development of military footwear. In recent years, this effort has followed the pattern of data collection, analysis and synthesis, application and testing. In this paper, available sources of anthropometric data on the foot are reviewed and several types of analyses are discussed. Several examples of the applications of anthropometric measurement and analysis are presented.



50. *The hands of New World primates, with comparative functional observations on the hands of other primates.*<sup>1</sup> G. E. Erikson, Department of Anatomy, Harvard Medical School.

The range of locomotor adaptations found in the New World primates can be found in the Old World only by surveying the full order from tree shrews to anthropoid apes. There are three primary types: (1) general springing arboreal quadrupeds, (2) brachiating monkeys, and (3) an intermediate group of climbing monkeys.

In one little-noted feature, however, certain of the brachiator group (*Lagothrix* and the marginal member, *Alouatta*) and certain of the intermediate group (*Pithecia*, *Chiropotes*, and *Cacajao*) differ strikingly from the others: the functional cleft in the hand in grasping small branches and in holding small objects is that between the index and middle fingers. Photographs of captive animals in the field<sup>2</sup> demonstrate this "opposition" of the thumb and index finger to the other three digits. This grasp would seem to be unique to these five genera but should not be dismissed as a peculiar platyrrhine specialization of little general relevance. Closer study of the hands of certain more primitive platyrrhines, lorisoidea, lemuroids, tupaioidea, and marsupials reveals a clear functional division of the digits at this same interval. The close correspondence in structure and function here suggests that this represents the retention of a generalized mammalian trait and signifies more than the various "zygodactylous" adaptations to be found in certain amphibians, reptiles and birds. The human hand also shows elements of this feature in its grasp, in contrast with the specialized, brachiating hand of anthropoid apes.

<sup>1</sup> Supported by grants from the Wenner-Gren Foundation for Anthropological Research.

<sup>2</sup> On expeditions supported by grants from the Guggenheim Foundation and from Harvard University.

51. *Neanderthal taurodontism.* F. Clark Howell, Department of Anthropology, University of Chicago. *Abstract not submitted.*

52. *The presence of organic structure in fossilized bone.* Ellis R. Kerley, Anthropology Department, University of Michigan.

A method is presented for the demonstration of organic structural material in fossilized bone, utilizing histologic techniques and microscopic examination under polarized light. The specimens used were from Sterkfontein, South Africa. The material from this site has been dated from 500,000 to 1,000,000 years old. The problem involved concerns the relationship of bone matrix to fossil specimen over an extended period of time.

The material used was cut into pieces of appropriate size and imbedded in Ward's Bioplastic. It was then cut into thin slices by a hydraulically lubricated abrasive wheel. Each section was mounted on a cork by means of paraffin and ground to minimal thickness on a lap wheel with No. 320 and No. 600 grit. The ground section was then washed in Xylene and absolute alcohol and liberally soaked in a Parlodion solution. The specimen was mounted on a standard microscopic slide and covered with glass.

Microscopic examination demonstrated the presence of both compact and trabecular matrices. Haversian canals were present in spite of the heavy mineral replacement in the fossilized specimens. In general the microscopic structure of the bone appeared to be normal and not unduly compressed or distorted, except along obvious lines of fracture. It would appear from the specimens examined that organic material persists in fossilized bone for a considerable length of time—probably as far back as the beginning of the Pleistocene. It appears also, that there is little if any distortion of the original bone matrix by the mineral replacement of fossilization.

53. *The estimation of body dimension variability.* Edmund Churchill, USAF Anthropometric Project, Antioch College. *Abstract not submitted.*

54. *Are body dimensions linearly correlated?* Alma M. Kuby and Edmund Churchill, USAF Anthropometric Project, Antioch College. *Abstract not submitted.*

55. *Chronologies of human sexual maturation: the theory of the attainment curve.* Edward E. Hunt, Jr., Adolescent Unit, Children's Hospital, and Forsyth Dental Infirmary for Children, Boston; and Department of Anthropology, Harvard University.

Where stages of maturation have been defined and applied to a sample of children, it is convenient to record the percentages of individuals who are at or beyond a stage as related to their ages. Such distributions may be transformed into a so-called "attainment curve." If grouped data are available, a convenient method is to plot the percentages on log probability paper. In this case, age is transformed into the logarithm of conceptional age, and the percentages of individuals into standard scores around a zero point at which 50% of the population are at or beyond the given stage.

In studies of both dental development and sexual maturation, attainment curves on log probability paper tend to form straight lines. For stringent theoretical reasons, a succession of attainment curves for stages of development within one organ tend to be parallel. Tests of parallelism between different organs are valuable indications of their systematic or integrated relationships with one another.

This method of recording the chronology of developmental stages has great generality, versatility and elegance, and can conveniently be attempted whenever data are available on children of varying ages and degrees of maturation. With little computational effort, the method can provide an abundance of information such as the variability of the group in attaining its stages of development, a developmental age equivalent for each stage, and at any desired age, the incidence of children in the population who are within each stage.

A crude method was devised of computing the equations of parallel attainment curves. This procedure was applied to the stages of sexual maturation which had been recorded in 226 boys at a New England boarding school. These students had also been somatotyped by Sheldon's technique. A study was therefore carried out which related body build and the trajectories of sexual maturation in these boys.

Allometric equations relating most of the subgroups to the total series revealed the timing and velocity of maturation in boys of different physiques.

The present findings agreed with those of many previous authors that mesomorphy is associated with early maturation. In predominantly mesomorphic boys, the attainment of the stages is slightly more variable than the average, and the velocity of maturation is about average.

The association of ectomorphy with late maturation has long been known. In our group, the variability of attaining the stages is low in ectomorphs, and the velocity 44% faster than the average. This rapidity of development is suggestive of a physiologic over-response to the increasing production of androgens and other trophic hormones which occurs in adolescence.

Although the endomorphic sample is small, it shows high variability in the age of attainment of stages, an early onset and a late ending of sexual maturation. The velocity is therefore low.

The present data indicate that caloric nutriture and body composition are related to sexual maturation in a way which might well be clarified by animal experimentation.

56. *Xeroradiography—a new technique for living anatomy.* Russell W. Newman, Quartermaster Research and Development Command, Natick, Massachusetts.

Operational procedures of a new radiographic medium, Xeroradiography, are illustrated and explained. This technique which uses photosensitized selenium-coated plates instead of conventional X-ray film and utilizes a dry developing method emphasizes small, sharp discontinuities in bone with a remarkable presentation of soft parts detail. Its speed of development, absence of sensitivity to background radiation, and wide density latitude make it appear ideal for use in a military war dead identification program as a method of locating and analyzing healed bone fractures.

57. *Further observations on the heterozygous carriers of phenylketonuria.* David Yi-Ying Hsia, Kathleen Driscoll, and Richmond Paine, Children's Medical Center, Boston, and Department of Pediatrics, Harvard Medical School.

58. *Hereditary control of phenylalanine and tyrosine metabolism in man.* Stanley Gartler and Richard Tashian, Institute for the Study of Human Variation, Columbia University.

59. *Congenital Factor VII (proconvertin) deficiency: Mode of inheritance.* Bertram L. Hanna and Henry G. Kupfer, Departments of Biology and Genetics and Clinical Pathology, Medical College of Virginia.

In 1949 a coagulation factor in serum was described which appears to act with tissue thromboplastin to accelerate the rate of conversion of prothrombin into thrombin (Factor VII, proconvertin, SPCA and other names). Individuals deficient in Factor VII may present a clinical picture indistinguishable from hemophilia. Deficiency may occur during dicumarol therapy, following liver damage, in neonates with hemolytic disease or may be present at birth without apparent cause.

Several families have been reported in which more than one congenital deficiency occurs. Information of genetic interest is found in six of thirty-eight families reported in the medical literature. However, in only two of these were tests specific for Factor VII utilized in the diagnoses, and in each of these two, study was limited to the family line presenting a history of hemorrhagic disease. Either simple autosomal dominant (Frick and Hagen, 1953) or autosomal partial dominant inheritance (Quick, et al, 1955) will explain the patterns observed in these families. Fifty-two clinically normal relatives of our Factor VII deficient probanda were studied using tests specific for this factor. Both parents were found to have mild sub-clinical deficiencies of Factor VII, and a reduced level was found to segregate in three generations of both families. From examination of the family and from comparisons of the variation in Factor VII assay among sub-clinically deficient and among normal family members with each other and with a control "normal" sample, it is concluded that heterozygosity for an abnormal allele results in a reduction of measurable Factor VII and homozygosity in a severe deficiency. The variation in assay method, within individual variation, the distributions among normal males and females and the distributions among samples collected by different techniques are examined and discussed.

60. *The mathematical relations among plural birth frequencies.* Gordon Allen and I. Lester Firschein, National Institute of Mental Health, and Institute for the Study of Human Variation, Columbia University.

Any kind of plural birth should be numerically related to the next higher order derived from the same number of zygotes by the probability of embryonic division multiplied by the number of embryos capable of dividing. If  $a$  and  $b$  are the population frequencies of MZ and DZ twins, respectively, the expected frequencies of MZ, DZ and TZ triplets are approximately  $2a^2$ ,  $2ab$  and  $b^2$ . The four types of quadruplets are given by the terms  $6a^3$ ,  $6a^2b$ ,  $3ab^2$  and  $b^3$ . Within each zygosity class, for each type of plural birth, the probabilities of the various sex-concordance types can be predicted in simple fractions. When these two sets of probabilities are combined, close statistical agreement is found with data for triplets of three different races and, in Whites, for quadruplets and quintuplets. The total numbers predicted, however, suggest prenatal losses on the order of twenty per cent for White triplets and thirty-five per cent for White quadruplets.

The proposed formulas provide approximate probabilities for use in zygosity calculations in high-order plural births.

61. *Mean matrimonial radius and exogamy index in Brazilian populations.* N. Freire-Maia and A. Freire-Maia, Laboratory of Genetics, University of Parana, Curitiba, Parana, Brazil.

62. *An index of consanguinity.* R. F. Shaw, Graduate School of Public Health, University of Pittsburgh.

63. *Fertility and viability of offspring in consanguineous marriages.* Herman M. Slatis, Raymond H. Reis, and Robert E. Hoene, Argonne National Laboratory and Marquette University.

64. *Empiric risks in consanguineous marriage. Birth weight, gestation time, and measurements of infants.* N. E. Morton, Department of Anatomy, University of Wisconsin.

Offspring of unrelated parents, first cousins, first cousins once removed, and second cousins have been examined in three Japanese cities. The reliability and validity of the data are discussed. Taking account of relevant nongenetic variables, the dysgenic effects of inbreeding are estimated for birth weight, gestation time, and measurements of infants at the age of 8-10 months. For length of gestation and head girth no effect is detected. There is a small but significant decrease in weight, height, and chest girth with inbreeding. However, even for first cousins the decrease in size is only a few dkg. for weight and a few mm. for height and chest girth. There is no significant effect of inbreeding on the variances of these measurements. The eugenic effects of "isolate-breaking" and of the prohibition of cousin marriage on body size are discussed, and it is concluded that these effects are likely to be quite small.

65. *Empiric risks in consanguineous marriage. Malformation, stillbirths, and neonatal and infantile deaths.* W. J. Schull, Department of Human Genetics, University of Michigan.

To the extent that recessive genes contribute to the occurrence of major congenital malformations or perinatal deaths, one may expect, on a genetic basis, an increase in the frequency of these events among the offspring of related parents.

The data to be reported are a by-product of a comprehensive attempt, in the years 1948-1955, to obtain detailed information concerning the various possible late or delayed biological effects of exposure to an atomic bombing. Some 4,845 pregnancy terminations in Kure, Hiroshima, and Nagasaki occurring to parents related as first cousins, first cousins once removed, or second cousins have been studied. These parents as well as the parents of some 63,796 control infants (parents unrelated) were either unexposed or received trivial amounts of irradiation. There should, then, be no confounding of irradiation and non-irradiation effects.

Within these data, it can be shown that parental relationship is significantly associated with the frequency of major congenital malformations, and with the frequency of perinatal deaths among infants exhibiting at birth no clinically recognizable, gross abnormality. In both instances, the frequencies increased as parental relationship increased. This association is satisfactorily represented by a linear regression of the frequency of congenital malformations or perinatal deaths on the coefficient of inbreeding. There is no evidence that this association is due to such concomitant variation as differences in maternal age, parity, etc., among the classes of parental relationship.



66. *Hereditary leiomyoma of the skin.* H. Warner Kloepper, John Krafchuk, Vincent Derbes, and James Burks, Tulane University.

67. *Problems in comparing the tooth eruption sequence in fossil and modern man.*<sup>1</sup> Stanley M. Garn, Kalevi Koski and Arthur B. Lewis, Fels Research Institute for the Study of Human Development, Antioch College, Yellow Springs, Ohio.

The order of eruption of the permanent teeth has been extensively used in comparing fossil hominids to recent man and to the higher primates. Schultz gives the order  $M_1, I_1, I_2, M_2, (P_1, P_2), C, M_3$  for "fossil man," as contrasted to  $(M_1, I_1), I_2, (P_1, C, P_2), M_2, M_3$  for "recent whites." Broom and Robinson distinguished *Paranthropus* from all anthropoids on the basis of the presumed eruption sequence though admitting the  $M_2P_2$  order.

Of necessity, clinical eruption, that is the order of appearance through the gums, cannot be utilized for fossil remains and for most primate material. In its stead, any of three substitute sequences have been employed. These include the formation sequence (as determined by x-ray), the sequence of alveolar eruption, and the order of reaching the occlusal level. As shown by longitudinal analysis of contemporary Fels children, these substitute sequences are not necessarily identical to clinical eruption, and not necessarily equivalent to each other. The  $M_2P_2$  sequence in formation or alveolar eruption may become  $P_2M_2$  in clinical eruption or in the order of reaching the occlusal level.

In view of these findings reported specific and generic differences in the order of eruption must now be re-evaluated using the same system of analysis throughout.

<sup>1</sup> Supported in part by United States Public Health Service grant M 1260 from the National Institute of Mental Health.

68. *Tooth eruption sequence in fossil and modern man.* Kalevi Koski,<sup>1</sup> Stanley M. Garn and Arthur B. Lewis, Fels Research Institute for the Study of Human Development, Antioch College, Yellow Springs, Ohio.

The literature on the tooth eruption sequence in fossils ascribed to *Homo* is reviewed in the light of knowledge gained from longitudinal records of dental development of modern white children. In many cases there have been incorrect observations, misinterpretations and even misquotations. These have come about because of insufficient knowledge and inability to distinguish between tooth eruption as seen in skeletal material and as seen in the living.

It appears that the eruption sequence in the *Sinanthropus* child (B I) would most likely have been  $P_2M_2$  instead of  $M_2P_2$  as claimed; in the cases of the Krapina, Le Moustier, Ehringsdorf and Afalou children the exact sequence of cutting through the gum remains unknown. The interpretations presented in the literature regarding the eruption sequence in *Australopithecus* and *Paranthropus* do not seem to be conclusively substantiated.

Considering the facts that the  $M_2P_2$  sequence is not uncommon in modern white children and even the  $M_2C$  sequence is occasionally encountered, the eruption sequence formula for modern *Homo* should be written:  $(M_1, I_1), I_2, (CP_1P_2M_2)M_3$ .

The conclusion is that the tooth eruption sequences in the known fossil hominoids and in the modern man are essentially similar and this developmental phenomenon cannot be used as a taxonomic criterion within the Hominoidae.

<sup>1</sup> Visiting Fulbright-Smith-Mundt research scholar, on leave of absence from the Institute of Dentistry, University of Helsinki, Finland.

69. *X-ray protection in studies of growth and development.* S. M. Garn, F. Silverman and L. W. Soutag, Fels Research Institute for the Study of Human Development, Antioch College, Yellow Springs, Ohio.

With the increasing chances of individual exposure to penetrating radiation from sources beyond individual control, it is important to provide maximum protection when x-rays are used for investigative purposes.

Since the amount of radiation employed in chest x-rays, long-bone x-rays, soft-tissue x-rays, etc., is small, these do not constitute a source of danger unless repeated to excess. The remaining concern, that of genetic mutations affecting the population in the distant future, can be met by adequate safeguards.

Besides the use of filters, and insistence on high-speed films and intensifying screens, radiation can be limited to the part involved, through the use of cones with adjustable lead diaphragms. The area of irradiation can further be reduced by aperture plates shaped to fit the plate proportions. Moreover, accidental direct gonadal radiation can be avoided by the use of lead-rubber flaps or shields.

The aim of all of these precautions is to minimize gonadal radiation to a point where it does not add appreciably to the natural background radiation. Even in a longitudinal growth study, continued on through adulthood, total gonadal doses can be kept far below the present recommended tolerances of 10 r during the reproductive period.

70. *A study of monkey chromosome complements.*<sup>1</sup> Ernest H. Y. Chu and Norman H. Giles, Department of Botany, Josiah Willard Gibbs Research Laboratories, Yale University.

The karyotypes of relatively few Primates have been determined by modern cytological techniques now available, yet the need for such studies in the further elucidation of evolutionary mechanisms and relationships in this group of mammals is evident. The present brief report presents information on the chromosome complements of nine species (including two subspecies of one species) in one family of Old World monkeys, the *Cercopithecidae*. These studies indicate a notable variation in chromosome number and morphology in this group of related species.

Methods for determining chromosome complements involved the use of tissue cultures of kidney epithelial cells (kindly furnished by Drs. J. L. Melnick and C. D. Hsuing of the Yale Medical School). For cytological studies, two types of materials were used: (1) cell suspensions obtained by removing cells from the culture vessel walls by incubation with trypsin or versene solutions, and (2) cells proliferating on cover slips in depression (Leighton) tubes. In both procedures cells were pretreated with hypotonic saline to spread chromosomes and smear-stained with aceto-carmine. The chromosome numbers of the materials studied appeared to be essentially constant with very occasional polyploid and aneuploid cells.

Diploid chromosome counts were determined for the following species,<sup>2</sup> all Old World monkeys in the family *Cercopithecidae* (numbers in parentheses indicate the number of individuals examined): *Macaca mulatta*—Rhesus macaque—♂(3), ♀(1)—42; *Papio papio*—Guinea baboon—♀(1)—42; *Papio doguera*—Olive baboon—♂(2)—42; *Cercocebus torquatus lunulatus*—White-crowned mangabey—♂(2)—42; *Erythrocebus patas*—Military red-grass monkey—♂(1), ♀(3)—54; *Cercopithecus aethiops sabaeus*—African green monkey—♂(1)—60; *Cercopithecus aethiops tantalus*—African white monkey—♂(2), ♀(1)—60; *Cercopithecus diana rolaway*—Diana monkey—♂(1), ♀(1)—60; *Cercopithecus mona campbelli*—Campbell's monkey—♀(2)—66; *Cercopithecus nictitans buttikeri*—White nose or spotted nose monkey—♀(3)—66. (All counts but those for *Macaca mulatta* and *Papio papio* were determined for the first time in these studies as far as the authors are aware.)

Preliminary studies on chromosome morphology indicate general similarities in the various species: three types of chromosomes with respect to centromere positions are present—those with median-submedian, those with subterminal, and those with nearly terminal centromeres; males of all species studied have morphologically similar XY sex chromosome pairs; each species has a single pair of autosomes with a pronounced secondary constriction, which, on general evidence, is the nucleolus-organizing pair.

The fact that all diploid chromosome numbers in these species are multiples of six suggests polyploidy as a possible evolutionary mechanism. However, there is considerable evidence against this possibility: the total length of each chromosome complement in the nine species is about the same despite the marked differences in chromosome number, and only one pair of sex chromosomes as well as only one pair of nucleolus-organizing chromosomes are present in each complement. It appears more likely that in the present group of species, differences in chromosome number have arisen from alterations in only a few chromosomes of a basic set, giving either larger or smaller numbers of chromosomes with little loss of chromosomal material.

A more extensive discussion of these results is being published elsewhere (American Naturalist).

<sup>1</sup>This research has been supported in part under a research contract, AT(30-1)-872, with the Atomic Energy Commission.

<sup>2</sup>Species identifications were made by Mr. T. Donald Carter, Department of Mammals, American Museum of Natural History, New York City.

#### BENEFACTORS

Wenner-Gren Foundation  
for Anthropological Research, Inc.

The Wistar Institute  
of Anatomy and Biology

## LIST OF OFFICERS AND MEMBERS

OFFICE	OFFICERS	TERM EXPIRING
<i>President</i>	W. MONTAGUE COBB	1959
<i>Vice-President</i>	JOSEPH B. BIRDELL	1958
<i>Secretary-Treasurer</i>	JAMES N. SPUHLER	1960
<i>Executive Committee:</i>	WILLIAM W. HOWELLS	1958
	WILLIAM C. BOYD	1959
	WILLIAM W. GREULICH	1960

*Members*

- ACHESON, DR. ROY M., The Moyne Institute, Trinity College, Dublin, Ireland.
- ADAMS, MR. ROBERT M., JR., Room 310, Oriental Institute, University of Chicago, Chicago 37, Illinois.
- ADAMS, MR. WILLIAM R., 707 Anita Street, Bloomington, Indiana.
- AGINSKY, DR. BURT W., 911 Park Avenue, Apartment 10-B, New York City 21, N. Y.
- AGINSKY, DR. ETHEL G., 911 Park Avenue, Apartment 10-B, New York City 21, N. Y.
- ALBERTS, MR. BOB, Logan Museum of Anthropology, Beloit College, Beloit, Wisconsin.
- ALEXANDER, LT. MILTON, A03016787, Box 7807, WADC, Wright-Patterson Air Force Base, Ohio.
- AMES, DR. DAVID, Department of Anthropology, University of Wisconsin, Madison 6, Wis.
- ANDERSON, DR. J. E., Department of Anatomy, University of Toronto, Toronto 5, Canada.
- ANGEL, DR. J. L., Anatomy Department, Jefferson Medical College, 307 S. 11th Street, Philadelphia 7, Pa.
- ARCUNI, MISS JANET K., 153 Bayview Avenue, Inwood 96, N. Y.
- ARKIN, MRS. FRIEDA, 600 West 116th Street, New York 25, N. Y.
- ASHMAN, DR. RICHARD, 5902 Marshall Foch St., New Orleans, La.
- ASLING, DR. C. WILLET, Department of Anatomy, University of California, Berkeley 4, Calif.
- AVIS, MISS VIRGINIA, Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Ill.
- AYER, DR. ANANTHANARAYANA, Director of Institute of Anatomy, Stanley Medical College, Madras 1, India.
- BABY, MR. RAYMOND S., Ohio State Museum, Columbus 10, Ohio.
- BAER, FRANCES (MRS. ARTHUR BAER), 2713 Wisconsin Avenue N.W., Washington 7, D. C.
- BAER, DR. MELVYN J., Merrill Palmer School, 71 East Ferry Street, Detroit 2, Mich.
- BAERREIS, DR. DAVID A., Department of Anthropology, Sterling Hall, University of Wisconsin, Madison 6, Wisconsin.
- BAILEY, DR. RALPH, 405 Neches Street, Jacksonville, Texas.
- BAKER, DR. PAUL T., Physical Anthropology Br., QM. R & D Command, Natick, Mass.

- BAKWIN, DR. HARRY, 132 E. 71st Street, New York 21, N. Y.
- BARBOUR, DR. GEORGE B., University of Cincinnati, Cincinnati, Ohio.
- BARNICOT, DR. N. A., Department of Anthropology, University College London, Gower Street, London W.C. 1, England.
- BARTER, MR. JAMES T., 117 Glen Street, Yellow Springs, Ohio.
- BASEHART, DR. HARRY W., Department of Anthropology, University of New Mexico, Albuquerque, New Mexico.
- BASS, MR. WILLIAM MARVIN, III, 622 Yeadon Avenue, Yeadon, Pennsylvania.
- BATES, DR. MARSTON, Department of Zoology, University of Michigan, Ann Arbor, Michigan.
- BAYLEK, DR. THOMAS, 59 E. 54th Street, New York, N. Y.
- BENTON, DR. ROBERT S., Department of Anatomy, Medical College of South Carolina, Charleston 16, S. C.
- BIRDELL, DR. JOSEPH B., Department of Anthropology, University of California, Los Angeles 24, Calif.
- BJÖRK, DR. ARNE, The Royal Dental College, Department of Orthodontics, 4 Universitetsparken, Copenhagen, Denmark.
- BLOMQUIST, DR. HARRY E., Mannerheimvägen 19. A. 9, Helsingfors-Töölö, Finland.
- BOCK, MRS. RENÉE M. MENEGAZ, 6109 South Ellis Avenue, Chicago 37, Ill.
- BOÉSEN, DR. PREBEN, 4, Sct. Jorgens Vag, Lund, Sweden.
- BOISSEvain, DR. ETHEL (see Lesser).
- BOWLES, DR. GORDON, c/o International House of Japan, Inc., No. 2, Toriizaka, Azabu, Minato-ku, Tokyo, Japan.
- BOYD, MRS. LYLE G., 24 Edward Street, Belmont, Mass.
- BOYD, PROF. WM. C., Department of Biochemistry, Boston University School of Medicine, 80 East Concord Street, Boston 18, Mass.
- BRACE, MR. CHARLES L., 9710 T.U. Det. 2, Army Chemical Center, Edgewood, Maryland.
- BREITINGER, DR. EMIL, Franz Weidenreich-Institut der Universität Frankfurt am Main, Senckenberganalage 35, Frankfurt, West Germany.
- BROOKS, MRS. R. H., Department of Anthropology, University of California. Berkeley 4, California. (Sheilagh Thompson.)
- BROZEK, DR. JOSEF, Laboratory of Physiological Hygiene, Stadium Gate 27, University of Minnesota, Minneapolis 14, Minnesota.
- BRUES, DR. ALICE, University of Oklahoma School of Medicine, 801 E. 13th Street, Oklahoma City 5, Okla.
- BRUNER, DR. EDWARD, Department of Anthropology, Yale University, New Haven, Connecticut.
- BÜCHL, DR. ERNST C., Department of Anthropology, 27 Chowringhee, Calcutta 13, India.
- BUCHANAN, DR. JOSEPH, Hospital for Joint Diseases, 960 Park Avenue, New York City 28, N. Y.
- BUEFTNER-JANUSCH, DR. JOHN, Anthropology Department, University of Michigan, Ann Arbor, Mich.
- BULLEN, MRS. ADELAIDE K., Florida State Museum, Gainesville, Fla.
- BUSWELL, MR. J. O., III, Department of Anthropology, Wheaton College, Wheaton, Illinois.
- BUTTS, DR. DONALD C. A., 125 First Street N.W., Winter Haven, Fla.



- CAMP, DR. CHARLES L., Department of Paleontology, University of California, Berkeley 4, Calif.
- CAMPBELL, DR. BERRY, Anatomy Building, University of Minnesota, Minneapolis 14, Minn.
- CAUDILL, DR. WILLIAM, Psychological Clinic, 64 Plympton Street, Cambridge 38, Mass.
- CHANG, DR. SHIN-YO, College of Medicine, Seoul National University, Seoul, Korea.
- CHARLES, DR. CECIL MARVIN, 110 South Central Avenue, Clayton 5, Missouri.
- CHARNEY, MR. MICHAEL, Hackensack Biochemical Laboratory, 271 Union Street, Hackensack, N. J.
- CHOPRA, DR. S. R. K., Department of Anatomy, University of Birmingham Medical School, Hospitals Centre, Birmingham 15, England.
- CHOWN, DR. BRUCE, 735 Notre Dame Ave. Winnipeg 3, Canada.
- CHURCHILL, DR. EDMUND, USAF Anthropometrie Project, Antioch College, Yellow Springs, Ohio.
- CLAUSER, MR. CHARLES E., 1 Briar Road, Muncie, Indiana.
- COCKE, MRS. GRACE L., Bay State Apartments, 1572 Massachusetts Avenue, Apartment 13, Cambridge 38, Mass.
- COLBY, MISS HELEN J. (see Fleischer).
- COLE, MR. GLEN H., Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Ill.
- COLIN, DR. EDWARD C., 900 East 83rd Street, Chicago 19, Ill.
- COLLINS, DR. HENRY B., JR., Smithsonian Institution, Washington 25, D. C.
- COLONNA, DR. PAUL, Department of Orthopedic Surgery, Hospital of the University of Pennsylvania, 3400 Spruce Street, Philadelphia 4, Pa.
- COMAS, DR. JUAN, Instituto Indigenista Iuteramericana, Alberto Zamora 69, Coyoacan, D. F., Mexico.
- COOLIDGE, H. J., 2424 California Street, Washington 8, D. C.
- COON, DR. CARLETON S., University Museum, University of Pennsylvania, Philadelphia 4, Pa.
- CORNWELL, DR. WILLIAM S., 350 Westminster Road, Rochester 7, N. Y.
- COSENTINO, MR. JOHN A., 15 Wellesley Road, Upper Montclair, N. J.
- COUNT, DR. EARL W., Anthropology Department, Hamilton College, Clinton, N. Y.
- CRAFT, MISS CHARLENE (see LeFebvre).
- CRAVEN, DR. A. H., Department of Orthodontics, University of Michigan, School of Dentistry, Ann Arbor, Michigan.
- CRAWFORD, MISS MARY R., Laboratory of Physical Anthropology, John Hopkins University, Baltimore 18, Maryland.
- CRESSMAN, DR. L. S., Department of Anthropology, University of Oregon, Eugene, Oregon.
- CUMMINS, DR. HAROLD, Anatomy Department, Tulane University, New Orleans 18, Louisiana.
- CURETON, DR. THOMAS KIRK, 213 Huff Gymnasium, University of Illinois, Urbana, Illinois.
- DAHLBERG, DR. ALBERT A., 5756 S. Harper Avenue, Chicago 37, Illinois.
- DAMON, DR. ALBERT, Constitution Clinic, Columbia University College of Physicians and Surgery, 670 West 168th Street, New York 32, N. Y.

- DAMON, DR. SELMA THOMSEN, Constitution Clinic, Columbia-Presbyterian Medical Center, 670 West 168th Street, New York 32, N. Y.
- DANIELS, DR. GILBERT S., 1113 McDaniel Avenue, Evanston, Illinois.
- DÁVALOS HURTADO, DR. EUSEBIO, Museo Nacional de Anthropologia, Moneda 13, Mexico 1, D. F.
- DAWSON, DR. HELEN L., Anatomy Department, College of Medicine, University of Iowa, Iowa City, Iowa.
- DEL BOCA DI VILLAREGIA, Count Bernardino, Baluardo Partigiana 3, Novara, Italy.
- DE LUCCHI, MAJOR MILTON R., 1618 Burnwood Road, Baltimore 12, Maryland.
- DEMPSTER, DR. WILFRED T., Department of Anatomy, University of Michigan School of Medicine, Ann Arbor, Mich.
- DEPALMA, DR. ANTHONY F., 248 South 21st Street, Philadelphia 3, Pa.
- DEPENA, DR. JOAN FINKLE, Department of Anthropology, Indiana University, Bloomington, Indiana.
- DICE, DR. LEE R., Laboratory of Vertebrate Biology, University of Michigan, Ann Arbor, Michigan.
- DOBZHANSKY, DR. TH., Department of Zoology, Columbia University, New York 27, N. Y.
- DU BRUL, DR. E. LLOYD, College of Dentistry, University of Illinois, 808 So. Wood Street, Chicago 12, Ill.
- DUGGINS, DR. OLIVER H., JR., 10 Alden Lane, R.F.D. no. 2, Creve Coeur, Mo.
- DUNCAN, DR. DONALD, 114 Tarpon, Galveston, Texas.
- DUNN, DR. LESLIE C., Department of Zoology, Columbia University, New York City 27, N. Y.
- DUPERTIUS, DR. C. WESLEY, Western Reserve University School of Medicine, Cleveland 6, Ohio.
- DYSON, DR. ROBERT H., University Museum of the University of Pennsylvania, 33rd and Spruce Streets, Philadelphia 4, Pa.
- EADS, DR. WILLIAM F., 1651 Garnet Street, San Diego 9, California.
- EHRIICH, DR. ROBERT W., Anthropology Department, Brooklyn College, Brooklyn, N. Y.
- EISELEY, DR. LOREN C., Anthropology Department, University of Pennsylvania, Philadelphia 4, Pa.
- ELKINS, MR. AARON, Department of Anthropology, University of Arizona, Tucson, Arizona.
- EMANUEL, MR. IRVIN, Box 82, Strong Memorial Hospital, Rochester 20, N. Y.
- EPLING, MR. PHILIP J., Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Ill.
- EPSTEIN, MR. JEREMIAH F., Anthropology Division, Hunter College, 695 Park Avenue, New York City 21, N. Y.
- ERICKSEN, MRS. MARY F., U. S. Geological Survey, Foreign Branch, Washington 25, D. C.
- ERICKSON, DR. G. E., Department of Anatomy, Harvard Medical School, 25 Shattuck Street, Boston 15, Mass.
- ESTEL, DR. LEO A., Sociology and Anthropology Department, Ohio State University, Columbus 10, Ohio.
- EVANS, DR. F. G., College of Medicine, Wayne State University, 1401 Rivard Street, Detroit 7, Mich.

- EWING, REV. J. FRANKLIN, S. J., Fordham University, New York 58, N. Y.
- FALKNER, DR. FRANK, Department of Pediatrics, University of Louisville School of Medicine, Louisville 2, Kentucky.
- FARRIS, DR. EDMOND J., The Wistar Institute of Anatomy and Biology, 36th Street at Spruce, Philadelphia 4, Pa.
- FEJOS, DR. PAUL, Wenner-Gren Foundation for Anthropological Research, 14 East 71st Street, New York 21, N. Y.
- FELTS, DR. WILLIAM J. L., Department of Anatomy, University of Minnesota, Minneapolis 14, Minn.
- FIELD, DR. HENRY, 3551 Main Highway, Coconut Grove 33, Fla.
- FIRSCHER, MR. LESTER, Institute for the Study of Human Variation, Columbia University, 413 West 117th Street, New York 27, N. Y.
- FLEISCHER, HELEN J., Oak Hill Road, Harvard, Massachusetts.
- FLYNN, DR. J. E., Biological Abstracts, University of Pennsylvania, Philadelphia 4, Pa.
- FREEDMAN, DR. ARTHUR, 1000 N. Elm, Greensboro, N. C.
- FRIEDL, DR. ERNESTINE, 401 East 75th Street, New York City 21, N. Y.
- FRY, MR. EDWARD I., Department of Anthropology, University of Nebraska, Lincoln, Nebraska.
- FUJITA, DR. TSUNETARO, Department of Anatomy, University of Tokyo, Bunkyo-Ku, Tokyo, Japan.
- GABEL, DR. NORMAN E., Department of Social Sciences, Santa Barbara College, Santa Barbara, Calif.
- GARN, DR. STANLEY M., Fels Research Institute for the Study of Human Development, Antioch College, Yellow Springs, Ohio.
- GATES, PROF. R. R., Department of Anthropology, Harvard University, Cambridge 38, Mass.
- GAVAN, DR. JAMES A., Department of Anatomy, South Carolina Medical College, 16 Lucas Street, Charleston 16, South Carolina.
- GEJVALL, DR. NILS-GUSTAF, Academy of History and Antiquities, Osteological Department, Storgatan 41, Stockholm Ö, Sweden.
- GENOVES, DR. SANTIAGO CARLOS, Instituto de Historia, Torre de Humanidades, Ciudad Universitaria, Mexico 20, D. F.
- GERTLER, DR. MENARD M., 98 Riverside Drive, Apt. 10A, New York 24, N. Y.
- GILES, PVT. EUGENE, US56276154, 601st FA Msl Bn, APO 872, New York, N. Y.
- GILLETTE, DR. CHARLES E., Curator of Archeology, N. Y. State Museum, Albany 1, N. Y.
- GILLIN, DR. JOHN P., 204 Alumni Building, University of North Carolina, Chapel Hill, N. C.
- GIVENS, MR. RICHARD D., 1409 South Missouri Avenue, Mercedes, Texas.
- GLASS, DR. BENTLEY, Department of Biology, Johns Hopkins University, Baltimore 18, Maryland.
- GODFREY, DR. WILLIAM S., Logan Museum of Anthropology, Beloit College, Beloit, Wisconsin.
- GOFF, DR. C. W., 30 Farmington Avenue, Hartford, Conn.
- GOLDSTEIN, DR. MARCUS S., Division of Public Health Methods, U.S. Public Health Service, Washington 25, D. C.
- GOSMAN, DR. S. D., 2 South Frontenac Avenue, Margate, N. J.

- GOSS, DR. CHARLES M., 2236 Dublin Street, New Orleans 18, La.
- GOULD, PROF. HARLEY N., Bio Sciences Information Exchange, 113 Dupont Circle Bldg., Washington 6, D. C.
- GRANBERRY, MR. JULIAN, Box 2255 University Station, Gainesville, Fla.
- GRANT, PROF. J. C. BOILEAU, Anatomy Department, University of Toronto, Toronto 5, Canada.
- GRAY, DR. DONALD J. Anatomy Department, Stanford University, Calif.
- GRAY, MISS MARGERY P., Department of Sociology and Anthropology, University of Wisconsin, Madison, Wisconsin.
- GRAY, DR. ROBERT F., Marshall, Minn.
- GREENE, DR. THEODORE C., 711 Deepdene Road, Baltimore 10, Md.
- GREGORY, PROF. WM. K., Box 535, Woodstock, N. Y.
- GREULICH, DR. W. W., Anatomy Department, Stanford University, Calif.
- GRUBER, DR. JACOB W., Department of Sociology, Temple University, Philadelphia 22, Pa.
- GUSINDE, PROF. MARTIN, Department of Anthropology, Catholic University of America, Washington 17, D. C.
- GUTTENTAG, DR. OTTO E., University of California Medical School, San Francisco 22, Calif.
- GUZE, DR. HENRY, 69 Hillside Avenue, Newark 8, New Jersey.
- HAGER, DR. DON J., Commission on Community Interrelations, American Jewish Congress, Stephen Wise Congress House, 15 East 84th Street, New York City 28, N. Y.
- HALLORAN, MR. ARTHUR H., Wildlife Management Biologist, Wichita Mountains Refuge, Cache, Okla.
- HAMILTON, DR. JAMES B., Department of Anatomy, Long Island College of Medicine, 350 Henry Street, Brooklyn 2, N. Y.
- HAMLIN, DR. HANNIBAL, 270 Benefit Street, Providence 3, R. I.
- HANDY, DR. E. S. C., Box 57, Oakton, Va.
- HANIHARA, MR. KAZURO, Department of Legal Medicine, Sapporo Medical College, Nishi 17, Minami 1, Sapporo, Hokkaido, Japan.
- HANNA, DR. BERTRAM L., Department of Biology and Genetics, Medical College of Virginia, Richmond 19, Va.
- HARPER, MISS RUTH, Fels Research Institute, Antioch College, Yellow Springs, Ohio.
- HARPER, DR. WALTER F., Department of Anatomy, University College of the West Indies, Mona, St. Andrew, Jamaica.
- HAYWARD, DR. BOYD, 3138 East McDowell Road, Phoenix, Arizona.
- HEGLAR, MR. RODGER, Department of Anthropology, University of Washington, Seattle, Wash.
- HEIZER, DR. ROBERT F., Department of Anthropology, University of California, Berkeley 4, Calif.
- HENDERSON, MR. GERALD, Department of Sociology and Anthropology, Brooklyn College, Brooklyn 10, N. Y.
- HERNDON, DR. C. NASH, Department of Medical Genetics, Bowman Gray School of Medicine, Winston-Salem, N. C.

- HERSKOVITS, DR. MELVILLE J., Anthropology Department, Northwestern University, Evanston, Ill.
- HERTZBERG, H. T. E., 414 N. Park Place, Yellow Springs, Ohio.
- HEUSE, DR. GEORGES A., 167 Rue de Rennes, Paris VI<sup>e</sup>, France.
- HIGGIN, DR. DAVIDA M. WOLFFSON, Department of Anthropology, University College London, Gower Street, London W.C.1, England.
- HILL, DR. W. C. OSMAN, Zoological Society of London, Regents Park, London, N.W. 1, England.
- HJELMMAN, DR. GÖRAN, Institute of Anatomy, University of Helsinki, Siltavuorenpenger 20, Helsinki, Finland.
- HJORTSJÖ, DR. CARL-HERMAN, Director, the Anatomical Institution at the University of Lund, Biskopsgatan 7, Lund, Sweden.
- HOEBEL, DR. E. A., Ford Hall, University of Minnesota, Minneapolis 14, Minnesota.
- HOLCOMB, DR. GEORGE R., Department of Anatomy, School of Medicine, University of North Carolina, Chapel Hill, North Carolina.
- HOOLJER, DR. DIRK ALBERT, Rijksmuseum van Natuurlijke Historie, Leiden, Netherlands.
- HOTTON, DR. NICHOLAS, III, Department of Anatomy, University of Kansas, Lawrence, Kansas.
- HOWELL, DR. FRANCIS CLARK, Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Ill.
- HOWELLS, DR. W. W., Peabody Museum, Cambridge 38, Mass.
- HOWORTH, DR. BECKETT, 1 Atlantic, Stamford, Conn.
- HOYME, MISS LUCILE E., 10 Museum Road, Oxford, England.
- HULSE, DR. FREDERICK S., Department of Anthropology, University of Washington, Seattle, Wash.
- HUNT, DR. EDWARD EYRE, JR., Forsyth Dental Infirmary, 140 The Fenway, Boston 15, Mass.
- HUNT, MRS. VILMA R., Forsyth Dental Infirmary, 140 The Fenway, Boston 15, Mass.
- HURME, DR. V. O., Forsyth Dental Infirmary, 140 The Fenway, Boston 15, Mass.
- JAMES, DR. ALICE, Anthropology Division, Hunter College, New York 21, N. Y.
- JAY, MRS. PHYLLIS J., 831 East 60th Street, Chicago 37, Ill.
- JENSEN, DR. DOROTHY CROSS, Department of Anthropology, Hunter College, 695 Park Avenue, New York City 21, N. Y.
- JENSEN, DR. ELLI, Royal Danish Dental College, Universitetsparken 4, Copenhagen, Denmark.
- JONES, MRS. BONNIE M., Chemotherapy Division, Southern Research Institute, Birmingham 5, Alabama.
- KANSU, PROF. SEVKET AZIZ, Anthropoloji Enstitüsü, Dil ve Tarih-Cografya Fakültesi, Ankara Üniversitesi, Ankara, Turkey.
- KAPLAN, MR. ARNOLD R., Department of Zoology, University of Texas, Austin 12, Texas.
- KAPLAN, DR. BERNICE, c/o Dr. G. W. Lasker, 1401 Rivard Street, Detroit 7, Mich.
- KAPLAN, DR. E. B., 1001 Grand Concourse, New York 52, N. Y.
- KARVONEN, DR. MARTTI J., Institute of Occupational Health, Helsinki, Finland.
- KELSO, MR. ALEC JOHN, Department of Anthropology, University of Michigan, Ann Arbor, Michigan.



- KERLEY, MR. ELLIS, Anthropology Department, University of Michigan, Ann Arbor, Michigan.
- KERN, DR. HOWARD M., JR., Naylor Lane, Pikesville 8, Maryland.
- KEUR, DR. DOROTHY L., 2475 Palisade Avenue, New York 63, N. Y.
- KING, DR. ARDEN R., Middle American Research Institute, Tulane University, New Orleans 15, La.
- KLATSKY, DR. MEYER, 520 Montgomery Street, Brooklyn 25, N. Y.
- KLEINDIENST, MISS MAXINE R., Box 129, Superior, Wyoming.
- KLUCKHOHN, DR. CLYDE, Peabody Museum, Cambridge 38, Mass.
- KOSKI, DR. KALEVI P., Institute of Dentistry, Fabianinkatu 24, Helsinki, Finland.
- KRAHL, DR. V. E., Anatomy Department, University of Maryland, 29 S. Greene Street, Baltimore 1, Md.
- KRAUS, DR. BERTRAM S., Department of Orthodontics, School of Dentistry, University of Washington, Seattle, Wash.
- KRAUSE, MISS GRETCHEN R., 1532 Cardiff Road, Columbus 21, Ohio.
- KROGMAN, PROF. WILTON M., Philadelphia Center for Research in Child Growth, 1701½ Fitzwater Street, Philadelphia 46, Pa.
- KROPP, DR. BENJAMIN N., Department of Histology and Embryology, Queen's University, Kingston, Ontario, Canada.
- LACHMAN, DR. ERNEST, College of Medicine, University of Oklahoma, 801 E. 13th Street, Oklahoma City 5, Okla.
- LANIER, DR. RAYMOND R., Department of Radiology, University of Colorado Medical Center, 4200 East 9th Avenue, Denver 7, Colorado.
- LAPIDUS, DR. PAUL W., 1133 Park Avenue, New York 28, N. Y.
- LASKER, DR. GABRIEL W., Department of Anatomy, Wayne University College of Medicine, 1401 Rivard St., Detroit 7, Michigan.
- LAUGHLIN, DR. WILLIAM S., Department of Sociology and Anthropology, University of Wisconsin, Madison 6, Wisconsin.
- LAY, MR. TRACY, Department of Anthropology, University of California at L. A., Los Angeles 24, California.
- LEFEBRE, MRS. C. T., Box 979, Central Point, Oregon.
- LESER, DR. PAUL W., Department of Anthropology, Hartford Seminary Foundation, 55 Elizabeth Street, Hartford 5, Conn.
- LESSA, DR. WM. A., Anthropology Department, University of California, Los Angeles 24, Calif.
- LESSER, DR. ETHEL BOISSEvain, Castle Point, Hoboken, N. J.
- LEVENE, DR. HOWARD, Department of Mathematical Statistics, Columbia University, New York 27, N. Y.
- LEVINE, DR. PHILIP, Ortho Research Foundation, Route 29, Raritan, N. J.
- LEVINE, DR. VICTOR E., School of Medicine, Creighton University, Omaha 2, Neb.
- LEWIS, MISS MARION, 735 Notre Dame Ave., Winnipeg 3, Canada.
- LINDEGÅRD, DR. BENGT, University of Lund, Biskopsgatan 7, Lund, Sweden.
- LIPTAK, DR. P., Magyar Nemzeti Múzeum, Természettudományi Múzeum, Ember-tani tár, Budapest, Vill., Baross-u., 13 Hungary.
- LITVAK, MRS. RUTH MARZANO, Department of Anatomy, University of Chicago Medical School, Chicago 37, Ill.
- LIVINGSTONE, MR. FRANK B., Department of Anthropology, University of Michigan, Ann Arbor, Michigan.

- LLOYD, DR. RUTH SMITH, Anatomy Department, Howard University, Washington 1, D. C.
- LONGYEAR, DR. JOHN M., III, Department of Sociology and Anthropology, Colgate University, Hamilton, N. Y.
- LUDWIG, MR. FRED, Route 2, Box 737, Tucson, Arizona.
- LUSTERMAN, DR. E. A., 165 North Village Avenue, Rockville Centre, Long Island, N. Y.
- LYSELL, DR. LENNART, Department of Orthodontics, Royal School of Dentistry, 17 Hölländargatan, Stockholm, Sweden.
- MACK, DR. PAULINE B., Dean, College of Household Arts, Texas State College for Women, Denton, Texas.
- MACKAL, DR. ROY PAUL, Department of Biochemistry, University of Chicago, 947 East 58th Street, Chicago 37, Illinois.
- MAINLAND, PROF. DONALD, Department of Medical Statistics, New York University-Bellevue Medical Center, 550 First Avenue, New York 16, N. Y.
- MAJUMDAR, DR. D. N., Chairman, Department of Anthropology, Lucknow University, Lucknow, India.
- MARANJIAN, MR. GEORGE, 384 N. Bedford Street, East Bridgewater, Mass.
- MARSHALL, MR. DONALD, Peabody Museum of Salem, East India Maine Hall, Salem, Mass.
- MARZANO, MISS RUTH A., see Litvak.
- MASSLER, DR. MAURY, University of Illinois College of Dentistry, 808 South Wood Street, Chicago 12, Illinois.
- MATSON, DR. G. A., Minneapolis War Memorial Blood Bank, 1914 La Salle Street, Minneapolis 4, Minn.
- MAYER-OAKES, DR. WILLIAM J., Carnegie Museum, Department of the Carnegie Institute, Pittsburgh 13, Pa.
- MCCLOY, DR. C. H., Division of Physical Education, State University of Iowa, Iowa City, Iowa.
- MCCONVILLE, MR. JOHN T., Department of Anthropology, University of Arizona, Tucson, Ariz.
- MCCOWN, MRS. ELIZABETH RICHARDS, 1114 Oxford Street, Berkeley 7, Calif.
- MCCOWN, DR. THEODORE D., Anthropology Department, University of California, Berkeley 4, Calif.
- MCGREGOR, DR. JOHN C., Department of Anthropology, University of Illinois, Urbana, Illinois.
- McKERN, MR. THOMAS W., Division of Physical Anthropology, U. S. National Museum, Washington 25, D. C.
- MEDNICK, MRS. LOIS WELLS, Department of Anthropology, University of Oregon, Eugene, Oregon.
- MEREDITH, DR. H. V., W-510 East Hall, State University of Iowa (Iowa Child Welfare Research Station), Iowa City, Iowa.
- MICHELSON, DR. NICHOLAS, Veterans Administration, Castle Point, N. Y.
- MIDLO, DR. CHARLES, 1404 Louisiana Avenue, New Orleans 15, La.
- MILES, MISS MERYL, Anatomy Department, University of Wisconsin, Madison 6, Wis.
- MILES, MISS SUZANNA, Peabody Museum, Cambridge 38, Mass.

- MILGRAM, DR. JOSEPH, Hospital of Joint Diseases, 1919 Madison Avenue, New York City 35, N. Y.
- MILLER, DR. ALOYSIUS I., Department of Anatomy, Emory University Medical School, Emory University, Georgia.
- MITCHELL, DR. MATTHEW, Philadelphia Center for Research in Child Growth, 1701½ Fitzwater Street, Philadelphia 46, Pa.
- MONTAGU, DR. M. F. ASHLEY, Cherry Hill Road, Princeton, N. J.
- MOODY, DR. PAUL A., Department of Zoology, University of Vermont, Burlington, Vermont.
- MOORREES, DR. COENRAAD F. A., Forsyth Dental Infirmary, 140 The Fenway, Boston 15, Massachusetts.
- MORRIS, MR. DONALD HARVEY, Department of Anthropology, University of Arizona, Tucson, Arizona.
- MOSS, DR. MELVIN L., Anatomy Department, Columbia University College of Physicians and Surgeons, 630 West 168th Street, New York City 32, N. Y.
- MURRILL, DR. RUPERT, Dyche Museum, University of Kansas, Lawrence, Kansas.
- MUSTAKALLIO, DR. MARTTI J., Institute of Anatomy, University of Helsinki, Silta vuorenpenger 20, Helsinki, Finland.
- NATHAN, DR. HILEL, Department of Anatomy, the Hebrew University-Hadassah Medical School, Jerusalem, Israel.
- NEUMANN, DR. GEORG K., Department of Anthropology, Indiana University, Bloomington, Ind.
- NEWMAN, DR. MARSHALL T., U. S National Museum, Washington 25, D. C.
- NEWMAN, DR. RUSSELL W., Environmental Protection Division, Quartermaster Research and Development Center, Natick, Massachusetts.
- NICHOLS, MR. PETER W., Department of Anthropology, University of Arizona, Tucson, Arizona.
- NOBACK, DR. CHARLES R., Anatomy Department, College of Physicians and Surgeons, 630 W. 168th Street, New York 32, N. Y.
- NOURSE, DR. DOLORES VAN C., Columbia University, Bureau of Applied Social Research, 605 West 115th Street, New York 27, N. Y.
- NUSSBAUM, DR. WILLIAM, 82-31 Austin Street, Kew Gardens, L. I. 15, N. Y.
- OAKLEY, DR. KENNETH PAGE, Anthropology Section, British Museum (Natural History), Cromwell Road, London, S. W. 7, England.
- O'DELL, DR. H. W., The Akron Clinic, 513 West Market Street., Akron 3, Ohio.
- ORTTUNG, MRS. JANE RAVEN, Department of Anthropology, American Museum of Natural History, New York 24, N. Y.
- OSBORNE, DR. RICHARD H., Department of Medicine, College of Physicians and Surgeons, 620 West 168th Street, New York 32, N. Y.
- OSCHINSKY, DR. LAWRENCE, 25 Knolls Crescent, Riverdale, Bronx, New York.
- OTTEN, MISS CHARLOTTE, Department of Anthropology, University of Michigan, Ann Arbor, Mich.
- OVENBURG, MR. PETER H., Department of Zoology, University of Michigan, Ann Arbor, Mich.
- PAPEZ, PROF. JAMES W., Laboratory for Biological Research, 1960 West Broad Street, Columbus 15, Ohio.
- PAUL, DR. BENJAMIN D., School of Public Health, Harvard University, 1 Shattuck Street, Boston 15, Massachusetts.

- PAULS, MR. FRANK, Senior Medical Officer, Public Health Laboratory Project, P.O. Box 17, Teheran, Iran.
- PEDERSEN, DR. P. O., National Dental College of Denmark, 4 Universitetsparken, Copenhagen, Denmark.
- PETTAY, MISS LOUANA, Department of Anthropology, Indiana University, Bloomington, Indiana.
- PHILIPPAS, DR. GEORGE G., 8 Hippokratous Street, Athens, Greece.
- PLANANSKY, DR. KAREL, Veterans Administration Hospital, Canandaigua, N. Y.
- PLATT, MR. RICHARD A., 3624 Baring Street, Philadelphia 4, Pennsylvania.
- PLOUGH, PROF. H. H., Department of Biology, Amherst College, Amherst, Mass.
- POLLITZER, MR. WILLIAM, 413 W. 117th Street, New York 27, N. Y.
- POPE, MRS. BETTY L., Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Ill.
- POPHAM, DR. ROBERT E., Brookside Clinic, 9 Bedford Road, Toronto, Canada.
- POPOFF, MISS JOAN NELLIE, Fels Research Institute for the Study of Human Development, Yellow Springs, Ohio.
- PROST, MR. JACK H., Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Ill.
- PLYE, DR. IDELL, Department of Maternal and Child Health, Harvard School of Public Health, 55 Shattuck St., Boston 15, Mass.
- RABKIN, DR. SAMUEL, 511 Sylvan Drive, Winter Park, Fla.
- RACHER, DR. ALICE BRO, 356 Dogwood, Park Forest, Illinois.
- RAINEY, DR. FROELICH, University Museum of the University of Pennsylvania, 33rd and Spruce Streets, Philadelphia 4, Pa.
- RAY, DR. LESTER J., Department of Anatomy, University of Melbourne, Melbourne, Australia.
- REED, DR. CHARLES A., University of Illinois College of Pharmacy, 808 S. Wood Street, Chicago 12, Illinois.
- REED, DR. ERIK K., 238 Griffin Street, Santa Fe, N. M.
- REED, PROF. LOWELL J., School of Hygiene and Public Health, Johns Hopkins University, Baltimore 5, Maryland.
- REYNOLDS, DR. EARLE L., c/o Lurton Blassingame, 10 East 43rd Street, New York 17, N. Y.
- RICCIARDELLI, MR. ALEXANDER F., 1546 East 34th Street, Brooklyn 34, N. Y.
- RIESENBERG, DR. SAUL H., Department of Anthropology, University of Hawaii, Honolulu, T. Hawaii.
- RIFE, DR. DAVID C., Department of Zoology, Ohio State University, Columbus 10, Ohio.
- RILEY, DR. CARROLL L., Museum, Southern Illinois University, Carbondale, Ill.
- ROBINSON, DR. J. T., Transvaal Museum, P.O. Box 413, Pretoria, South Africa.
- ROCHE, DR. Alex. F., Department of Anatomy, University of Melbourne, Melbourne, Australia.
- ROCHE, DR. MAURICE B., 3720 Washington Blvd., St. Louis, Missouri.
- ROGERS, PROF. S. L., 920 Martinez Street, San Diego 6, California.
- ROMANUS-KJELLGREN, DR. TORSTEN, Karolinska Institutet, Stockholm 60, Sweden.
- RONEY, DR. JAMES G., 225 37th Avenue, San Mateo, Calif.
- ROSENFELD, DR. RICHARD E., 51 East 90th Street, New York City 28, N. Y.

- ROSS, DR. WILLIAM J., Michigan State University, The Basic College, East Lansing, Mich.
- ROWE, DR. CHANDLER W., Department of Anthropology, Lawrence College, Appleton, Wisconsin.
- SALZANO, DR. FRANCISCO M., Instituto de Ciencias Naturais, Av. Paulo Gama, Porto Alegre, Rio Grande do Sul, Brazil.
- SALZMANN, DR. J. A., 654 Madison Avenue, New York 21, N. Y.
- SANGHVI, DR. L. D., Indian Cancer Research Centre, Bombay 12, India.
- SANGVICHEN, DR. SOOD, Department of Anatomy, Faculty of Medicine and Siriraj Hospital, University of Medical Sciences, Bangkok, Thailand.
- SARNAS, DR. KARL V., State Dental School, Malmö 7, Sweden.
- SARNAT, DR. BERNARD G., 435 North Roxbury Drive, Beverly Hills, Calif.
- SAUL, MR. FRANK P., Lazy S Ranch, 190 Hyde Road, Yellow Springs, Ohio.
- SAUNDERS, DR. J. B. DEC. M., Anatomy Department, Medical School, University of California, Parnassus and 2nd Avenues, San Francisco 22, California.
- SAVARA, DR. BHIM, University of Oregon Dental School, 809 NE. 6th Avenue, Portland 14, Oregon.
- SAWIN, DR. PAUL B., Roscoe B. Jackson Memorial Laboratory, P.O. Box 847, Bar Harbor, Maine.
- SCHEPERS, DR. G. W. H., Institute of Industrial Health, University of Michigan, Ann Arbor, Michigan.
- SCHÖN, MR. MIGUEL ANTONIO, Department of Anthropology, University of Michigan, Ann Arbor, Mich.
- SCHULL, DR. WILLIAM J., Heredity Clinic, University of Michigan, 1135 East Catherine St., Ann Arbor, Michigan.
- SCHULMAN, MR. AILON, Hadassah Medical Organization (Beth Mazmil), Jerusalem, Israel.
- SCHULTZ, PROF. ADOLPH H., Anthropologisches Institut der Universität, Sempersteig 3, Zürich 1, Switzerland.
- SCHUMAN, DR. ELIHU LEON, 51 Baker Avenue, Lexington, Mass.
- SCOTT, PROF. DONALD, 21 Kirkland Street, Cambridge 38, Massachusetts.
- SCOTT, DR. J. P., Roscoe B. Jackson Memorial Laboratory, P. O. Box 78, Bar Harbor, Maine.
- SEIB, DR. GEORGE, 2323 Lafayette Avenue, St. Louis 4, Missouri.
- SEIPEL, DR. CARL MICHAEL, State Dental School, Malmö 7, Sweden.
- SELBY, DR. SAMUEL, Fels Research Institute for the Study of Human Development, Antioch College, Yellow Springs, Ohio.
- SELTZER, DR. CARL C., 13 Holyoke Street, Cambridge 38, Massachusetts.
- SEN, MRS. TULIKA, 39/2c Monoharpukur Road, Calcutta 29, India.
- SENSENIQ, DR. E. CARL, Department of Anatomy, Medical College of Alabama, Birmingham 5, Ala.
- SENYÜREK, PROF. DR. MUZAFFER, CHAIRMAN, Division of Paleoanthropology, Dil ve Tarih-Coğrafya Fakültesi, Ankara Üniversitesi, Ankara, Turkey.
- SHADE, DR. CHARLES I., Production Dept., WHBQ-TV, 1381 Madison Ave., Memphis, Tennessee.
- SHANKLIN, DR. WM. M., American University, Beirut, Lebanese Republic.
- SHAPIRO, DR. H. H., Anatomy Department, Columbia University College of Physicians and Surgeons, 630 W. 168th Street, New York 32, N. Y.



- SHAPIRO, DR. H. L., American Museum of Natural History, New York 24, N. Y.
- SHELDON, DR. WILLIAM H., Constitution Clinic, Columbia University College of Physicians and Surgeons, 670 West 168th Street, New York City 32, N. Y.
- SILLMAN, DR. J. H., 667 Madison Avenue, New York 22, N. Y.
- SILVERMAN, DR. FREDERIC N., Department of Roentgenology, The Children's Hospital, Cincinnati 29, Ohio.
- SIMMONS, DR. ROY T., Commonwealth Laboratories, Parkville, N. 2, Victoria, Australia.
- SINGER, DR. RONALD, Department of Anatomy, University of Cape Town Medical School, Mowbray, Cape Town, South Africa.
- SKARLAND, DR. IVAR, Department of Anthropology, University of Alaska, Box 11, College, Alaska.
- ŠKERLJ, DR. BOŽO, Resljeva 13, Ljubljana, Yugoslavia.
- SMITH, DR. R. DALE, Department of Anatomy, Creighton University School of Medicine, Omaha 2, Nebraska.
- SNODGRASSE, DR. R. M., Temple University School of Dentistry, Broad above Allegheny, Philadelphia 40, Pa.
- SNOW, DR. CHARLES E., Department of Anthropology, University of Kentucky, Lexington 29, Ky.
- SNYDER, MR. RICHARD G., 4828 East Grant Road, Tucson, Arizona.
- SONTAG, DR. L. W., Fels Research Institute for the Study of Human Development, Antioch College, Yellow Springs, Ohio.
- SPUHLER, DR. JAMES N., Department of Genetics, University of Michigan Medical School, 1135 East Catherine Street, Ann Arbor, Mich.
- STAGG, MR. FREDERICK L., Peabody Museum, Cambridge 38, Mass.
- STEEDMAN, PROF. ELSIE V., 21 West 58th St., Apt. 9E, New York 19, N. Y.
- STEKELIS, PROF. M., Department of Prehistoric Archaeology, Hebrew University, Jerusalem, Israel.
- STEWART, DR. T. D., U. S. National Museum, Washington 25, D. C.
- STRANGE, DR. HOWARD, 1912 West 103rd Street, Chicago 43, Illinois.
- STRAUS, DR. WILLIAM L., JR., Laboratory of Physical Anthropology, Mergenthaler Hall, Johns Hopkins University, Baltimore 18, Md.
- STUCKLEN, DR. RICHARD, 611 North Matlack Street, West Chester, Pa.
- SULLIVAN, DR. WALTER E., 118 Hathaway Drive, East, San Antonio 9, Texas.
- SWINDLER, DR. DARIS RAY, Department of Anatomy, West Virginia University, The Medical School, Morgantown, West Virginia.
- TANNER, DR. JAMES M., Institute of Child Health, Hospital for Sick Children, Great Ormond Street, London W.C. 1, England.
- TAPPEN, DR. NEIL C., Department of Anatomy, Emory University School of Medicine, Emory University, Georgia.
- TELKKÄ, DR. ANTTI J., Department of Anatomy, University of Helsinki, Silta-vuorenpenger 20, Helsinki, Finland.
- TERRY, PROF. ROBERT J., School of Medicine, Washington University, St. Louis 10, Mo.

- THIEME, DR. FREDERICK, Department of Anthropology, University of Michigan, Ann Arbor, Mich.
- THOMAS, DR. WILLIAM L., JR., Division of Social Sciences, University of California, Riverside, Calif.
- THOMPSON, MISS PATRICIA, 817½ East Speedway, Tucson, Ariz.
- THOMPSON, S. (see Brooks).
- THOMSEN, DR. SELMA Ø. (see Damon).
- TITIEV, DR. MISCHA, 2604 Brockman Blvd., Ann Arbor, Mich.
- TOBIAS, DR. PHILLIP V., Department of Anatomy, University of the Witwatersrand Medical School, Hospital Street, Johannesburg, South Africa.
- TOBIN, DR. WILLIAM J., 1835 Eye Street, N.W., Washington 6, D. C.
- TOWNSLEY, DR. WILLIAM, 306 Shankill Road, Belfast, Ireland.
- TROTTER, DR. MILDRED, Anatomy Department, Washington University, 4580 Scott Avenue, St. Louis 10, Mo.
- TRUEX, DR. R. C., Anatomy Department, Hahnemann Medical College, 235 N. 15th Street, Philadelphia 2, Pa.
- TURNER, MR. CHRISTY G., II, Department of Anthropology, University of Arizona, Tucson, Arizona.
- TURNER, MR. MALCOLM E. JR., Department of Statistics, N. C. State College, Raleigh, N. C.
- VANDERVAEL, DR. FRANZ A., Institut d'Anatomie, Université de Liège, Rue de Pitteurs 20, Liège, Belgium.
- VAN STONE, MR. JAMES, Department of Anthropology, Box 5, University of Alaska, College, Alaska.
- VAN WART, CAPT. FRANKLIN D., 370 Orton Road, Yellow Springs, Ohio.
- VERMA, MR. DURGESH KUMAR, Department of Anthropology, Lucknow University, Lucknow, U. P., India.
- VON BONIN, DR. GERHARDT, Anatomy Department, University of Illinois, 1853 W. Polk Street, Chicago 12, Ill.
- WASHBURN, DR. S. L., Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Illinois.
- WATKINS, DR. MARK HANNA, Howard University, Washington 1, D. C.
- WEDGWOOD, DR. RALPH J., Babies' and Children's Hospital, 2103 Adelbert Road, Cleveland 6, Ohio.
- WEISENGREEN, DR. H. HENRY, Section of Anatomy, College of Dentistry, University of California Medical Center, San Francisco 22, Calif.
- WENDORF, DR. FRED, JR., The Museum, Texas Technological College, Lubbock, Texas.
- WHITE, MR. CHARLES B., School of Public Health, University of California, Berkeley 4, Calif.
- WHITE, DR. ROBERT, Environment Protection Division, QM Research and Development Command, Natick, Mass.
- WIENER, DR. ALEXANDER S., 64 Rutland Road, Brooklyn 25, N. Y.
- WILBER, DR. C. G., Applied Physiology Branch, Chemical Corps Medical Laboratories, Army Chemical Center, Edgewood, Maryland.
- WOLFFSON, DAVIDA M. (see Higgin).
- WOMBLE, MR. WILLIAM H., 2900 Cliff Drive, Newport Beach, Calif.

- WOO, DR. JU-KANG, Laboratory of Vertebrate Palaeontology, Academia Sinica, Peking, China.
- WORMINGTON, DR. H. MARIE, Denver Museum of Natural History, City Park, Denver 6, Colorado.
- WRIGHT, DR. HARRY B., 616 Medical Arts Building, Philadelphia, Pa.
- WULSIN, DR. F. R., Sociology Department, Tufts College, Medford 55, Massachusetts.
- YOUNG, MR. RICHARD W., Fels Research Institute, Yellow Springs, Ohio.

### *Life Members*

- ANDREWS, DR. JAMES M., 4860 Linnean Avenue, N. W., Washington 8, D. C.
- \* BALL, DR. ROBERT P., Oak Ridge Hospital, Oak Ridge, Tennessee.
- \* BODEL, DR. JOHN K., Hotchkiss School, Lakeville, Conn.
- \* BRIGGS, DR. L. CABOT, Hancock, N. H.
- \* COBB, DR. W. MONTAGUE, Department of Anatomy, Howard University, Washington 1, D. C.
- \* DANFORTH, PROF. CHARLES H., Anatomy Department, Stanford University, California.
- DEIGNAN, DR. STELLA LECHE, 2120 Bancroft Place, N. W., Washington 8, D. C.
- FORTUYN, DR. A. B. D., Julianalaan A, Oegstgeest, Holland.
- GOWER, PROF. CHARLOTTE D., (address not known).
- HUGHES, DR. BYRON O., University of Michigan, Ann Arbor, Mich.
- DE JONGE, DR. TH. E., University of Amsterdam, Biltscheweg 32, Bosch en Duin, Utrecht, Holland.
- LOO, DR. YU TAO, Chinese Association for the Advancement of Science, 235 Shensi Road (Southern), Shanghai, China.
- MILLS, DR. C. A., Cincinnati General Hospital, Cincinnati 29, Ohio.
- MORTON, DR. DUDLEY J., 14 E. 90th Street, New York 28, N. Y.
- OETTEKING, DR. BRUNO, Museum of American Indian, Broadway at 155th Street, New York 32, N. Y.
- PHILLIPS, DR. T. W., (address not known).
- PINKELY, DR. GEORGE, (address not known).
- \* POST, DR. RICHARD H., Quogue, L. I., N. Y.
- REDWAY, DR. LAURANCE D., 82 S. Highland Avenue, Ossining, N. Y.
- STEVENSON, DR. PAUL H., 700 North Charles Street, Baltimore 1, Maryland.
- TUCKER, DR. WILLIAM B., Veterans Administration Hospital, Fulton Street and Erwin Road, Durham, North Carolina.
- WILLIAMS, DR. GEORGE DEE, Chief, Physical Medicine Rehabilitation Service, Veterans Administration Center, Martinsburg, West Virginia.
- WOODBURY, DR. ROBERT M., c/o International Labour Office, Geneva, Switzerland.
- ZWEMER, DR. RAYMUND L., Chief, Science Division, The Library of Congress, Washington 25, D. C.
- \* Active life members.

GIFT TO THE UNIVERSITY OF PITTSBURGH  
by JOHN GILLIN

## TOOTH ERUPTION SEQUENCE IN FOSSIL AND MODERN MAN<sup>1</sup>

KALEVI KOSKI<sup>2</sup> AND STANLEY MARION GARN  
*Fels Research Institute, Antioch College, Yellow Springs, Ohio*

FIVE FIGURES

### INTRODUCTION

In the literature dealing with fossil man the dentition occupies a prominent rôle. Not only have the morphological aspects of the teeth been considered, but the developmental aspects have been stressed as well. Thus, for example, the sequence of eruption of the permanent teeth has been employed both as a taxonomic criterion and as a phenomenon presumably indicating evolutionary trends.

As pointed out in a previous paper (Garn, Koski and Lewis, '57) the criteria for "eruption" have not been the same for both fossil and living man. Yet most of the students of fossil man have failed to make the very necessary distinction between what can be observed in skeletal remains and what is known of living modern man. The line of distinction is, of course, the gum line which is the reference level for eruption in the living.

It is interesting to note that even so experienced a worker as Senyürek ('55) in his comprehensive review of the order of eruption of the permanent teeth in fossil hominids sets out to "review the literature on this subject to see what is definitely known about the order of eruption of the permanent teeth in the fossil hominids and to what extent they *resemble*

<sup>1</sup> Many of the findings in the present study are based on research conducted under grant M-1260 from the United States Public Health Service.

<sup>2</sup> Visiting Smith-Mundt Fellow in Physical Growth, January-June, 1957. Present address: Institute of Dentistry University of Helsinki, Helsinki, Finland.

the anthropoid apes and *differ* from the modern Europeans'' (italics ours). But, here Senyürek makes exactly the same errors as the authors whose works he is reviewing, by comparing observations made on the bony jaws with information gained from observations on living Europeans. And yet, Senyürek is fully aware of variations in the order of eruption of teeth in modern man (cf. Senyürek, '56), a fact that should have made him at least suspicious of the possible error in this procedure, even if he is, as were earlier authors, insufficiently aware of the actual sequence of events during calcification and eruption of the teeth. This knowledge of dental variability should have made him question the *a priori* assumption that fossil man "resembles" the anthropoid apes and "differs" from the modern man in the sequence of eruption of the teeth.

On the other hand, it is noteworthy that a few of the authors in the field of paleoanthropology have been cautious in regard to the eruption of teeth in the fossil man. For instance, Hooton ('46) does not mention the subject at all, and Straus (in his widely-quoted paper "The Riddle of Man's Ancestry") questions "the decisive nature of the dental features alone" (Straus, '49, p. 217).

In view of the importance attached to the eruption sequence by many authors, it may be worthwhile to re-examine some of the original reports dealing with the eruption sequence in particular fossils and to re-evaluate the findings and interpretations in the light of our present knowledge of dental development in the living. This is perhaps best done by observing how various criteria have been employed in estimating the sequence of eruption.

#### *Extrapolation from unerupted calcifying teeth*

Weidenreich ('36, '37) describes in great detail two juvenile mandibles of *Sinanthropus pekinensis*. In an attempt to establish an eruption sequence he relies on the location of the calcifying teeth in the jaw fragment identified as B-I, noting that the second molar is *close to the alveolar surface* while



the premolars are still deeply embedded (cf. fig. 1). In a second jaw, B-V, the posterior part carrying the molars is broken off and missing and only the following teeth are present: from right to left, the deciduous second molar, the first premolar, the right canine, 4 incisors, and the left canine.

On the basis of these two mandibles, Weidenreich draws the conclusion that "the permanent teeth *cut the gum*" (*italics ours*) in the order:  $M_1$   $I_1$   $I_2$   $M_2$   $P_1$   $C$   $P_2$   $M_3$ ! Considering the meager information or rather the lack of information, such a detailed sequence certainly would seem to stretch the data beyond the breaking point.

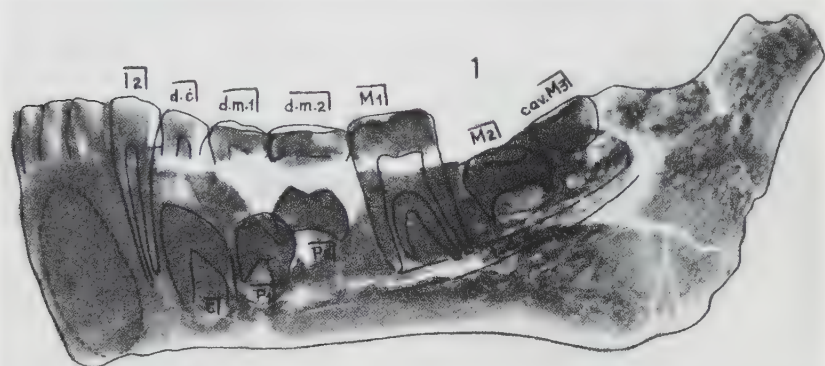


Fig. 1 Skiagram of the *Sinanthropus* B-I mandible reproduced (along with the overlay) from Weidenreich ('36, plate VI, fig. 1). Although Weidenreich ('37 pp. 122) assumed that  $M_2$  was "preparing to erupt" in this juvenile specimen because it was situated just below the surface of the alveolar process, and therefore assigned the  $M_2$  $P_1$  $P_2$  sequence of eruption, actually  $M_3$  was as much as 4 years away from gingival eruption. The most probable order of cutting the gum would be  $P_2$  $M_2$  for this *Sinanthropus* child, just as in contemporary white children!

Let us have a look at the mandible B-I, which, after all, may offer some clue as to the eruption sequence. The second molar and premolars have not yet completed the calcification of their crowns. In our experience (cf. Garn, Koski and Lewis, '57) a second molar at the stage of calcification evident

in the original roentgenogram, is never "preparing to erupt," as claimed by Weidenreich. In fact, using normative data in contemporary white children, an average of 26 months would be needed to bring a second molar from the stage of fully calcified crown to the stage of alveolar eruption, i.e., to the stage where its cusps would just project above the alveolar margin. And from this latter stage, an average of 15 months would be spent on its further journey to the occlusal level. It has been observed that the second molar becomes clinically visible, or "cuts the gum" when it has almost reached the occlusal level. This means, then, that the second molar of this particular *Sinanthropus* child would have needed more than 40 months to reach the gum-cutting stage, provided that the rate of eruption was the same as it is in modern children!

The situation regarding the *Sinanthropus* premolars is somewhat different. The average period of time spent from the stage of wholly calcified crown to the stage of alveolar eruption in modern children is 31 months for the first premolar and 33 months for the second premolar, but for the premolars alveolar eruption generally equals cutting the gum. Since the premolars and the second molar in B-I all seem to be at the same stage of calcification, it would be most likely that the premolars would have made their appearance through the gum earlier than the second molar. This conclusion is strengthened by our observation that the sequence  $M_2P_2$  or  $(P_2M_2)$  at any stage is more likely to change to a  $P_2M_2$  sequence during later development than vice versa (Garn, Koski and Lewis, '57). Thus, though the second premolar in *Sinanthropus* B-I was more deeply embedded in the jaw, as Weidenreich noted, this is the normal position, and it would probably have cut the gum before the second molar.

Here it may be permissible to examine the widely quoted paper by M. R. Drennan ('32) on the eruption sequence of Bushmen, since unerupted and calcifying teeth are used to "prove" the affinities of Bushmen with apes and Neanderthals.

Four roentgenograms of the lower molars and premolars are reproduced in Drennan's original paper, representing "the only examples" of Bushman children that give information about the eruption sequence, according to the author (fig. 2). One of these 4 children (D) obviously lacks the second premolar, since it is not visible in the roentgenogram.

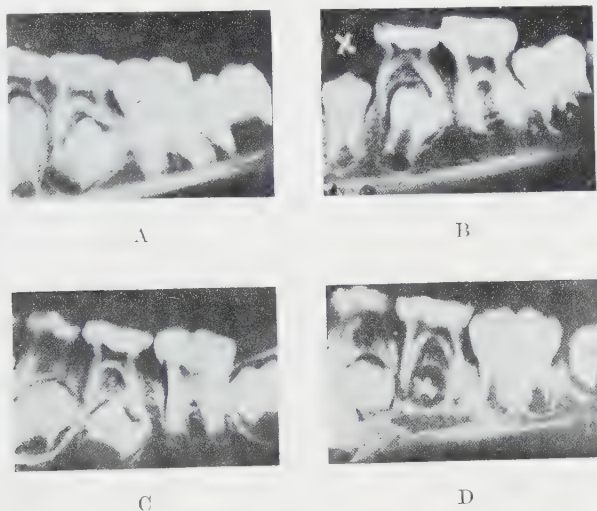


Fig. 2 Dental radiographs of 4 Bushman children originally published by Drennan as examples of his claim that the second molars are advanced over the premolars, "showing the same order of eruption as in the apes, and the direct inverse of that in the European" (Drennan, '32 pp. 494). However  $P_2$  is congenitally missing in D, both  $P_2$  and  $M_2$  are unerupted in C, and the order of cutting the gum would most likely be  $P_2M_2$  for the remaining two children, A and B. See text for further details.

In a second child (C) both  $P_2$  and  $M_2$  are still embedded in the jaw and the crowns are as yet incompletely calcified. Consequently, two of the 4 children pictured by Drennan contribute no information about the actual eruption sequence of the premolars and the second molar.

In the remaining two Bushmen children pictured by Drennan (A and D) the second molar has already passed the stage of alveolar eruption while the second premolar has not.

However,  $M_2$  and  $P_2$  seem to be at the same stage of calcification, in both cases. The order of cutting the gum cannot be predicted with certainty from these roentgenograms, but in our estimation the chances are at least equal for either combination —  $P_2M_2$  or  $M_2P_2$ .

Drennan's claim for the  $M_2P_2$  eruption sequence in his 4 Bushmen children is therefore not well supported by the 4 roentgenograms published by him. Furthermore, his statement that these 4 children are good representatives of the whole group is obviously wishful. However, since Drennan uses criteria similar to those used in evaluating the eruption sequence of Neanderthal men and the order of *alveolar* eruption is obviously  $M_2P_2$  in two cases, his conclusion that the eruption sequence in Bushmen and Neanderthal men is the same may not be disputed — as far as Bushmen A and D and selected Neanderthals are concerned. Obviously, however, this kind of evidence is insufficient to support Drennan's further conclusion that his Bushmen are "Neanderthaloid" in many respects.

#### *Interpretation of stages of eruption*

In some instances the eruption sequence has been derived from the various stages of eruption as seen in fossil specimens. Dart ('48) for example, describes a juvenile mandible of *Australopithecus prometheus* (fig. 3) as follows:

"... the second permanent molars are both fully erupted, and yet, although the first premolar on the left side has erupted, the one on the right is only half-erupted and the second premolars have not as yet emerged from their eruption canals. The well-worn second milk molar is still in position on the right side: while, on the left side, the crown of the second premolar is partially exposed as it lies in its eruption canal."

Dart then draws the conclusion that in this *Australopithecine* child the second molars erupted before the premolars, a conclusion with which Broom and Robinson ('51) and Senyürek ('55) later agree.

Now, as pointed out previously, the "successive" permanent teeth, i.e., teeth that succeed deciduous teeth, cut the gum very soon after the deciduous predecessors are shed; in them cutting the gum is equal or almost equal to the alveolar eruption stage. However, the so-called "accessive"

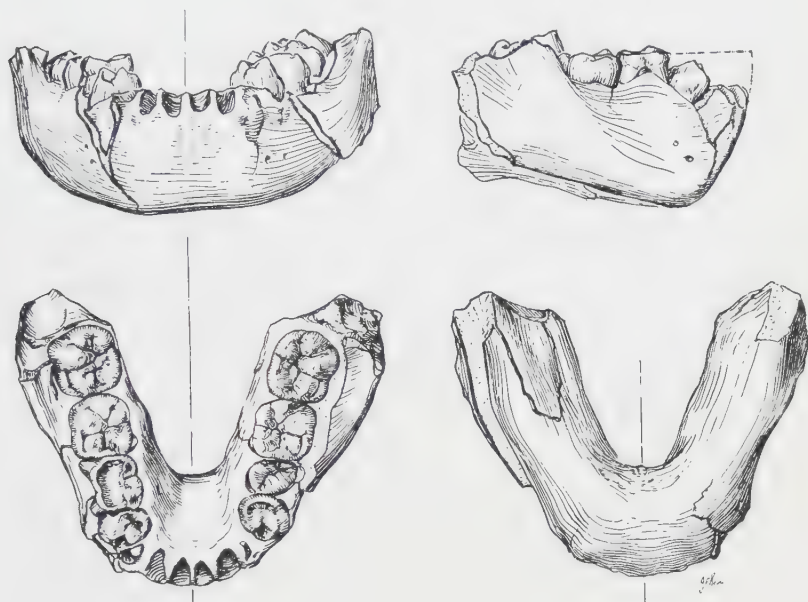


Fig. 3 The adolescent mandible attributed to *Australopithecus prometheus*, found at Makapansgat in 1947, reproduced from figure 1 in Dart ('48). Dart's description of this specimen states that "the second permanent molars are both fully erupted . . . The pattern in which the second molars erupt before the premolars . . . is found in the anthropoids and lower primates" (Dart, '48, pp. 394). However, it is doubtful that the permanent molars figured in this plate were actually in occlusion, or had cut the gum, whereas both second premolars were at or near the stage of eruption through the gum (see text). The existence of the  $M_2P_2$  pattern as characteristic of *Prometheus* is therefore questionable.

permanent teeth, the permanent molars, do not cut the gum until they nearly reach the occlusal level, being thus further emerged from the alveoli than the premolars, canines and incisors at the same stage. In other words, cutting the gum takes place well after the alveolar eruption stage in the molar



teeth, and almost at the alveolar eruption stage for the premolar teeth.

Applied to the *Prometheus* mandible this generalization means that we have no assurance for the second molar's priority in eruption at the gum-cutting stage despite its earlier *alveolar* eruption. Both of the first premolars are in a position that strongly indicates that they had already cut the gum. The right second milk molar is exposed far down to its roots, apparently about to shed, as the left antimere had already done. Both of the second premolars might therefore have cut the gum very soon after the age the child met his death. Furthermore, the second molar occupies a position medial to the ramus, which casts some doubt as to whether it had actually *cut the gum*. The fact that this tooth ( $M_2$ ) had reached the occlusal level is not proof for its being erupted through the gum, as we have mentioned in the previous section. Thus, the sequence of cutting the gum in this *Prometheus* specimen might best be indicated by the formula  $P_1 (M_2 P_2)$ , and not  $M_2 P_1 P_2$  as stated by Dart, and later accepted by numerous writers.

A somewhat similar condition to that in the *Prometheus* mandible is found in the half-mandible of the Krapina child C (described by Gorjanovic-Kramberger in '06), in which the second molar is already at the occlusal level, and the deciduous second molar is still in place. As Gorjanovic-Kramberger himself pointed out, the milk tooth is about to shed, which means that the underlying second premolar could have cut the gum shortly afterwards. Gorjanovic-Kramberger did not discuss the eruption sequence, being content with the morphology of the mandible. However, later authors have assigned an  $M_2 P_2$  sequence (cf. Weidenreich, '37; Senyürek, '55). In this case the possibility of a  $P_2 M_2$  sequence in cutting the gum is so slight that the Krapina child may indeed have had an  $M_2 P_2$  sequence, thus being a unique specimen among known Neanderthals.

Here, a recent study by Senyürek ('56) may be mentioned. Senyürek describes skeletal remains of "chalcolithic and

copper-age inhabitants of Anatolia," discussing the eruption sequence in these populations. His criteria are based on Schultz' definition of eruption, namely that "a tooth is considered to be erupting when the uppermost portion of its crown reaches clearly above and not merely to the alveolar stage." Senyürek finds that in many cases the second molar has preceded the premolars and canines in alveolar eruption. However, judging from the jaws pictured in his monograph, there is not one case where it is certain that the second molar would have cut the gum before the premolars and canines: in all except two (Kültepe No. 14, fig. 19, and Pazarli No. P. XI, fig. 21, as given in Senyürek, '56), it is most likely that the premolars and canines would have preceded the second molar in cutting the gum. Senyürek further discriminates between the "primitive condition, where the permanent canines and premolars erupt after the second permanent molars" and "the advanced condition, where the permanent canines and premolars appear before the second permanent molars," apparently without realizing that this discrimination is based on *different criteria of eruption* for skeletalized remains on one hand, and the living on the other hand. He then goes on to say:

"Although the study of Calcolithic and Copper Age inhabitants of Anatolia shows that the genetic changes, which brought about a shift from the primitive toward the modern condition in the order of eruption of permanent canines and premolars relative to the second molars, had taken place before the end of the fourth millenium B.C. and probably earlier, the available evidence from Anatolia as well as from Europe indicates that the high frequency of advanced condition, characteristic of the majority of recent whites, is a relatively recent development" (Senyürek, '56, p. 21).

The failure to make the distinction between alveolar eruption and gingival eruption obviates this conclusion; that it is also *de facto* incorrect, will become apparent in the course of the present paper.

Broom and Robinson claim that "the great collection of skulls . . . give satisfactory evidence of the sequence of eruption of the permanent teeth" in *Paranthropus crassidens*. Comparing their findings with some of the information available on monkeys, anthropoid apes and *Australopithecus* as well as on modern man, they come to the conclusion that the sequence in their *Paranthropus* "differs very markedly from that in all anthropoids and most monkeys, and agrees closely with that of modern man" (Broom and Robinson, '51). Further, they claim that "in this character it (i.e. *Paranthropus*) is much nearer modern man than is Pekin man, or Neanderthal man or even the Bushman." Broom and Robinson conclude that because of the differences in eruption sequence between *Australopithecus* and *Paranthropus*, they "have perhaps been right in holding that (their) South African ape-men belong to different species, and perhaps even to different genera." These taxonomic judgments appear quite unjustified if based on the obviously incomplete information on the eruption sequence.

A somewhat different problem in using eruption data is brought forth by Arambourg et al. ('34) in their discussion of the Afalou child No. 26. The authors note that both the first and second molars are in place, along with the first premolars. The second premolars have emerged but have not completely reached the level of the others. This could be interpreted as indicating  $M_2P_2$  sequence, even in attaining the occlusal level, a claim that Arambourg et al. did not make, however. But the degree of eruption of a tooth is governed, to some extent by its antagonists, which may have erupted earlier and may have erupted beyond the occlusal level of their neighbor teeth: this is not infrequently observed in the premolar region. As the lower premolars usually erupt earlier than the upper premolars, and since nothing is known of the lower dentition of this Afalou child, the possibility cannot be ruled out that the upper second premolars had been in occlusion, though not at the same level as the adjacent teeth. And in that case the  $P_2M_2$  sequence

could have obtained in Afalou No. 26, despite the relative position of P<sub>2</sub>.

### *Significance of attrition*

An example of the use of attrition as a possible indication of the eruption sequence is found in the discussion of the dentition of the *Sinanthropus* children (Weidenreich, '37, p. 121). Here Weidenreich mentions the scanty information available on the eruption of deciduous teeth in fossil man, and then adds:

“So much more important is the fact that we are able to make certain statements on the order of the eruption in *Sinanthropus*. In mandible B-IV all deciduous teeth are *in situ* and completely erupted. It is obvious, however, that the degree of attrition is very different. While the first incisor (the second being damaged) and the two molars are more or less worn, the canine is perfectly intact. This condition is fully in contrast to that of mandible B-I in which the permanent incisors are already in place, while the deciduous canines are worn up to about one-third of their height. Their integrity in the case of mandible B-IV therefore proves that they have undoubtedly erupted as the last ones of the whole series.”

This most important conclusion, apparently accepted at face value by Schultz ('44 *et seq.*), is open to criticism. First, direct evidence as to the eruption sequence is lacking (*vide supra*). The use of the degree of attrition as an indirect indication of eruption sequence is indeed a very dangerous one. Individual differences in attrition are great, even within the same dentition. Conceivably, the intercuspidation of the canines of the young *Sinanthropus* B-IV with their antagonists could have been such as to prevent the attrition of these teeth: no information regarding the occlusion is available as the maxilla is lacking. And in the *Sinanthropus* mandible B-I the explanation for the attrition of the deciduous canines could be that their occlusion with the antagonists has been such as to favor the attrition, especially since the latter specimen (B-I) is older than the former (B-IV). The *Sinan-*

thropus B-I child has passed the period of shedding the deciduous incisors and erupting the permanent incisors into occlusion, a period during which the masticatory stress in the anterior region has been directed solely on the canines. Weighing the situation carefully, we cannot agree with Weidenreich on the eruption order of the deciduous canines in *Sinanthropus*. Definite conclusions as to the sequence do not seem justified from the evidence presently available.



Fig. 4 Skiagram of the jaw of the Ehringsdorf child as originally received for study, reproduced from Virchow ('20, plate VII). Not only is the distance from  $I_2$  to the premolar implausibly great, but the presence of an unexfoliated deciduous molar (A) between a partly erupted premolar and a fully erupted molar is improbable.

#### *Reconstruction of a damaged jaw*

The Ehringsdorf child has been described as a "classic" example of the  $M_2P_2$  sequence. As originally received by Virchow ('20), the jaw was in a semi-restored state, having been badly damaged (see fig. 4). However, there was reason to question the restoration, and Virchow reassembled the parts, replacing a deciduous molar (originally placed between a partly erupted premolar and a fully erupted molar) with



a permanent molar found in the vicinity of the mandible during the excavation. Since the premolar is obviously a second premolar, Virchow's final restoration provided a premolar-molar row that is at least plausible (see fig. 5 in this paper).

The difference in degree of eruption between  $P_2$  and  $M_2$  led Virchow to assign the  $M_2P_2$  sequence to the Ehringsdorf child. However, the second molar is tilted posteriorly, indi-



Fig. 5 The Ehringsdorf jaw as restored, substituting a permanent molar (B) found near the jaw during excavation for the deciduous molar shown in figure 4. While Virchow assigned the  $M_2P_2$  eruption sequence to this specimen on the basis of the relative emergence of  $M_2$  and  $P_2$ , it is likely that, while  $P_2$  was already partially through the gum,  $M_2$  (still inclined posteriorly as during eruption) had not yet pierced the gum.

eating that it had not yet met its antagonists and therefore was not yet in occlusion; the lower molars in occlusion are forced to attain an anterior inclination. Consequently, the second molar in question may not even have pierced the gum. On the other hand, the second premolar almost certainly had already cut the gum, being so far emerged from its alveolus. Thus, the sequence in Ehringsdorf might have been  $P_2M_2$ . However, since the information on the reconstruction is somewhat incomplete, it is wiser to withhold judgment on the probable sequence until a later date.

*Eruption sequence in contemporary man*

"Eruption" as studied in contemporary man refers to the cutting of the gum. And while data on eruption have been extensively recorded, the actual sequence of eruption has been investigated in rather few studies (cf. Adler, '52; Gödény, '55a, '55b). Although tooth-eruption norms provide some indication of the prevalent sequence, they cannot reveal the degree of variation in the order of eruption. Students of fossil man have therefore been left little concrete information on the eruption sequence in modern man, a deficiency which they have not always realized when making comparisons between fossil and modern man.

For the last two decades most authors have relied on the sequence given by Schultz ('35, '44, '49, '50), according to whom the order of eruption of permanent teeth in modern man is:  $(I_1 M_1) I_2 (P C P) M_2M_3$  (cf. Schultz, '50).

However, as early as 1908 Ales Hrdlička published detailed studies on Apache and Pima children, including the dental formulae for a great many individuals. From these data the several eruption sequences can be computed, and the  $M_2P_2$  sequence turns out to be the most common in both tribes. Dahlberg and Epling have recently studied Pima children, and from unpublished data kindly made available to us, we have calculated the frequencies for  $M_2P_2$ ,  $M_2P_1$  and  $M C$  sequences in the lower jaw, which are 47.5, 6.3 and 6.7%, respectively.

In an English population, studied by Clements, Davies-Thomas and Pickett ('53), it was found that the mean eruption age for  $M_2$  was earlier than the mean eruption age for  $P_2$ . This indicates an extraordinarily high frequency of  $M_2P_2$  sequence in a modern white population, and we are inclined to agree with Senyürek ('55), who suspects that this finding is due to the sampling method (cf. Garn, Lewis and Shoemaker, '56). However the British authors state that all possible combinations of eruption sequences were encountered in the premolar-molar row, an observation that coincides with our own observations.

In a recent survey of Finnish children, conducted by the Finnish Center for Studies on Child Growth and Development, it was found that the frequencies of the  $M_2P_2$ ,  $M_2P_1$  and  $M\ C$  eruption sequences in the lower jaws were 15.5, 4.2 and 1.6%, respectively.

These few examples suffice to prove that the eruption sequence in modern man is a very variable phenomenon. Therefore, to include all normal variations encountered to date, the formula should perhaps be rewritten as:

$$(M_1\ I_1)\ I_2\ (C\ P_1\ P_2M_2)\ M_3.$$

It is apparent, when comparing this new formula with that given by Schultz ('50) for fossil man, that our formula encompasses the latter. The new formula is adequate for all groups described to date and includes the eruption sequences of the South African fossils described by Dart, and Broom and Robinson, possibly lending credence to their views on the homonid affinities of the South-African man-apes.

#### DISCUSSION

The literature on the eruption sequence in fossil man as well as some published studies on the order of eruption in more recent and contemporary man present a rather discouraging picture. It appears that not only have many authors been unaware of the basic aspects of dental development, but they have failed to exercise cautious judgment.

Indeed, in some instances workers have misinterpreted or misquoted findings to support their own contentions.

It is true that the kind of information on the sequence of events during calcification and eruption of teeth which is most needed, has not been readily available in the literature up to this time (cf. Garn, Koski and Lewis, '57). However, had earlier authors consulted standard textbooks of orthodontics or conferred with interested clinicians, they could have discovered that the molars do not cut the gum until they nearly reach the occlusal level, while the premolars emerge through the gum well before reaching the plane of occlusion. This information alone would have prevented many misinterpretations. That relevant information is not impossible to obtain is evident in Rohklin's report (Rohklin, '49), where both his eruption norms and his interpretation of calcification stages were based on actual observations of Russian children.

It appears that students of fossil man have, as far as teeth are concerned, been relying on their knowledge of the teeth of other fossil men and skeletalized primates. As long as they compared different fossil or skeletalized specimens with each other, no great harm was done. However, when they compared their findings on fossils (or other skeletal material) with findings based on living populations, two major errors were introduced. First, the distinction between alveolar eruption and cutting the gum was not made. Secondly, the existing variation in modern man was overlooked.

If alveolar eruption is the criterion for eruption, as it frequently has to be for skeletalized material, most of the conclusions regarding the similarities and dissimilarities of the eruption sequence are correct *as far as skeletalized specimens are concerned*. But, if the same criterion (alveolar eruption) is used in studying modern populations, the modal eruption sequence is immediately different from the order of gingival eruption, and is indeed similar to that found in skeletalized populations! Conversely, if the findings on the fossils are interpreted so as to be comparable to the observa-

tions on the living, we again find that there is no clear difference.

Uncritical acceptance of statements made by earlier authors seems to have been the unfortunate rule in paleo-odontology. The result has been an attempt to duplicate the claims of earlier authors, as pointed out in connection with Senyürek's recent studies. Perhaps the best example of this tendency is to be found in Weidenreich's work ('37, p. 122). He quotes the describers of *Le Mousteriensis Hauseri* cranium (Klaatsch and Hauser, '09), as having noted that "In the mandible of the Mousterian youth *all three permanent molars* are in place together with the left deciduous canine," and uses this statement to prove an  $M_1 M_2 M_3$ -C sequence in the Mousterian youth. Yet Klaatsch and Hauser ('09, p. 295) actually wrote that a fully developed left permanent canine "stands in the jaw underneath a small deeply-worn deciduous canine," and noted later that *none* of the third molars had yet erupted, as can be seen in the published photograph. Weidenreich's gross misquotation seems to have escaped observation hitherto. Since it supported his own belief in late canine eruption in fossil man, an erroneous belief as we have shown, this represents a classic case of compound error, a misquotation added to a misinterpretation.

In view of these observations, two major suggestions are obvious in regard to future work in paleo-odontology:

First, any student of the fossil dentition must have a thorough understanding of dental development and must make the distinction between what is seen in the skeletalized jaws and what is apparent through examination of the living.

And second, a thorough knowledge of the existing variation in dental development is an absolute prerequisite for any attempts to relate findings on fossil man to findings on modern man. To this end, far more information is needed on dental development in the various populations of modern man.



## SUMMARY

A re-evaluation of the literature on the tooth eruption sequence is presented and a number of misinterpretations, due to an inadequate knowledge of aspects of dental development, is revealed. The findings can be summarized as follows:

1. Many of the differences claimed to exist between fossil and modern man in regard to the eruption sequence are incorrect.

2. The eruption sequence in modern man is a variable phenomenon, as represented by the inclusive formula:

$$(M_1 I_1) I_2 (P_1 C P_2 M_2) M_3.$$

3. The sequence of tooth eruption cannot be used as a taxonomic criterion within known Hominids.

4. A most careful analysis of findings, based on adequate knowledge of dental development, is necessary when studying the dentition of fossil man. The distinction between findings in skeletalized material and in living man has to be made, and existing variation in modern man must be considered when attempts are made to compare extinct hominids with modern man.

## ACKNOWLEDGMENTS

The authors are indebted to Dr. A. A. Dahlberg for permission to quote from unpublished data. The valuable help of Mr. Paul Ebert, Librarian of The Fels Research Institute is gratefully acknowledged. Mrs. Lois A. Conklin assisted in the manuscript preparation.

## LITERATURE CITED

- ADLER, P. 1952 Az oldalso fogak valtodasanak sor-es idorendje. *Fogorv. Szle.*, 44: 262-266.
- ARAMBOURG, C. M., M. BOULE, H. VALLOIS AND R. VERNEAU 1934 Les grottes paléolithiques des beni Segoual (Algerie) *Arch. Inst. Paleontol. Humaine. Memoire*, 12 pp. 139-147.
- BROOM, R. AND J. T. ROBINSON 1951 Eruption of the permanent teeth in the South African fossil ape-men. *Nature*, 167: 443.
- CLEMENTS, E. M. B., E. DAVIES-THOMAS AND K. G. PICKETT 1953 Time of eruption of permanent teeth in British children in 1947-1948. *Brit. Med. J.*, 4825: 1421-1424.

- DART, R. A. 1948 The adolescent mandible of *Australopithecus prometheus*. *Am. J. Phys. Anthrop.*, n.s., 6: 391-409.
- DRENNAN, M. R. 1932 L'ordre d'éruption des dents permanentes chez les Boshimans. *L'Anthropologie*, 42: 491-495.
- GARN, S. M., K. KOSKI AND A. B. LEWIS 1957 Problems in determining the tooth eruption sequence in fossil and modern man. *Am. J. Phys. Anthrop.*, n.s., 15: 313-331.
- GARN, S. M., A. B. LEWIS AND D. W. SHOEMAKER 1956 The sequence of calcification of the mandibular molar and premolar teeth. *J. Dent. Res.*, 35: 555-561.
- GÖDÉNY, E. 1955a Die Typische Zahnformel zu verschiedenen Zeiten während der Wechselgebiss periode. *Zeit. für Altersforschung*, 8: 284-289.
- 1955b Normális, korai és kései fogzású gyermekek jellegzetes fogképlete Különböző életkorokban. *Orvosi Hetilap*. (Budapest), 3: 69-70.
- GORJANOVIC-KRAMBERGER, K. 1906 *Der Diluviale Mensch von Krapina in Kroatien*. C. W. Kreidel's Verlag, Wiesbaden.
- HOOTON, E. A. 1946 *Up from the ape*. MacMillan, New York.
- HRDLÍČKA, A. 1908 Physiological and medical observations among the Indians of Southwestern United States and Northern Mexico. Smithsonian Institution, Washington (Bur. Am. Ethnol. Bull. No. 34).
- KLAATSCH, H., AND O. HAUSER 1909 *Homo mousteriensis* Hauseri. *Arch. f. Anthropol. N.F.*, 7: 287-297.
- OSMAN HILL, W. C. 1954 *Man's ancestry: a primer of human phylogeny*. C. C. Thomas, Springfield, Ill.
- ROHKLIN, D. G. 1949 Certain data from a roentgenological examination of the child skeleton from the cave of Teshik-Tash, Southern Uzbekistan. pp. 109-113 in Gremiatski, M. A. (ed.) *Teshik-Tash: Palaeolithic Man*, Moscow State University, Moscow.
- SCHULTZ, A. H. 1935 Eruption and decay of the permanent teeth in primates. *Am. J. Phys. Anthrop.*, 19: 489-581.
- 1944 Age changes and variability in gibbons. *Am. J. Phys. Anthrop.*, n.s., 2: 1-129.
- 1949 Ontogenetic specializations of man. *Arch. D. Julius Klaus-Stiftung*, 24: 197-216.
- 1950 The physical distinctions of man. *Proc. Am. Phil. Soc.*, 94: 428-449.
- SENYÜREK, MUZAFFER 1955 A review of the order of eruption of the permanent teeth in fossil hominids. *Türk Tarih Kurumu Belleten*, 19: 407-444.
- 1956 Order of eruption of the permanent teeth in the Chalcolithic and Copper-age inhabitants of Anatolia. *Türk Tarih Kurumu Belleten*, 20: 1-28.
- STRAUS, W. L. JR. 1949 The riddle of man's ancestry. *Quart. Rev. Biol.*, 24: 200-223.
- VIRCHOW, HANS 1920 Die menschlichen Skeletreste aus dem Kämpfe'schen Bruch im Travertin von Ehringsdorf bei Weimar. Gustav Fischer, Jena.

- WEIDENREICH, F. 1936 The mandibles of *Sinanthropus pekinensis*: a comparative study. *Palaeontologica Sinica*, Series D, vol. 7, fasc. 3.
- 1937 The dentition of *Sinanthropus pekinensis*: a comparative odontography of the homonids. *Palaeontologica Sinica*, n.s. 1: 120–180.

# A COMPARISON OF THE PHYSICAL GROWTH AND DEVELOPMENT OF AMERICAN- BORN AND NATIVE JAPANESE CHILDREN <sup>1</sup>

WILLIAM WALTER GREULICH

*Department of Anatomy, Stanford University School of Medicine*

ELEVEN FIGURES

## INTRODUCTION

Some incidental observations which we had made over a period of years on children of Japanese ancestry living in California had given us the impression that these children are somewhat larger and, at least the younger ones, relatively longer-legged than children of the same sex and age whom we had studied in Japan (Greulich, Crismon, and Turner, '53). We decided to test our impression by measuring a representative sample of the Japanese children in this part of California, so that we might compare their standing height, sitting height, weight, sitting height/standing height ratio, and their skeletal development with those of their native Japanese counterparts. We were especially interested in comparing the skeletal development of the American-born Japanese children with that of the children in Japan since, so far as we are aware, no such radiographic observations have previously been made on children of Japanese ancestry in this country. This is a report of our findings on 898 of the children whom we measured and x-rayed in the San Francisco Bay area during 1956 and the early part of 1957.

Access to the children was obtained through the very generous cooperation of various school and church officials. No

<sup>1</sup> Aided by grant A-624 of the National Institutes of Health and a grant from the Wenner-Gren Foundation for Anthropological Research.

selection was exercised in choosing the children to be studied, except by omitting those whose parents did not sign and return the required authorization forms. Table 1 lists the number of boys and girls in each of the age-groups from 6 to 18 years on whom the data were collected.

TABLE 1  
*Number of children studied*

NUMBER	CHRONOLOGICAL AGE RANGE	MEAN	S.E.
B O Y S			
18	4.50 - 5.49	5.22	.05
47	5.50 - 6.49	6.03	.05
52	6.50 - 7.49	6.99	.04
33	7.50 - 8.49	7.99	.05
33	8.50 - 9.49	8.95	.05
33	9.50 - 10.49	9.98	.05
36	10.50 - 11.49	11.02	.05
29	11.50 - 12.49	11.98	.06
41	12.50 - 13.49	12.96	.04
34	13.50 - 14.49	14.00	.06
31	14.50 - 15.49	14.96	.05
27	15.50 - 16.49	16.09	.05
29	16.50 - 17.49	17.01	.06
22	17.50 - 18.49	17.88	.06
Total 465			
G I R L S			
13	4.50 - 5.49	5.13	.08
37	5.50 - 6.49	5.98	.05
34	6.50 - 7.49	7.05	.04
42	7.50 - 8.49	7.99	.04
30	8.50 - 9.49	8.88	.05
48	9.50 - 10.49	9.97	.04
33	10.50 - 11.49	10.98	.05
31	11.50 - 12.49	12.01	.05
35	12.50 - 13.49	12.94	.05
20	13.50 - 14.49	13.98	.07
34	14.50 - 15.49	15.08	.05
29	15.50 - 16.49	15.97	.06
27	16.50 - 17.49	17.00	.05
20	17.50 - 18.49	17.87	.07
Total 433			



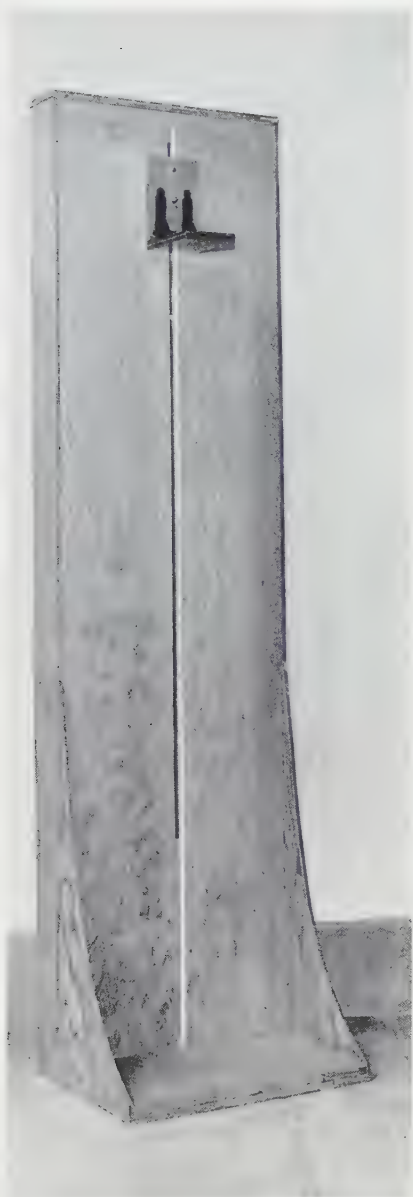


Figure 1A



Figure 1B

Fig. 1 The anthropometers used in determining standing height (1A) and sitting height (1B).

The standing height, sitting height, and weight of each child were recorded and a P.A. radiograph was made of the left hand and wrist, including the distal ends of the radius and ulna and all of the distal phalanges. The standing height and weight were determined after the subjects had removed their shoes and jackets or sweaters. In the case of the boys, we took the further precaution of having them empty their pockets before we weighed them, since the total weight of the contents of a boy's pockets is often considerable. In measuring the standing height and sitting height, we employed the anthropometers, designed and constructed by Mr. Yoshio Okumoto of our department, which are shown in figures 1A and 1B. The latter instrument together with the bench (16 inches [40.6 cm] high) shown in the same illustration was used in determining sitting height. The children were weighed on a Fairbanks scale of the beam type, the accuracy of which was checked at frequent intervals during the course of the study. In an attempt to achieve comparability in the data, all the measurements were made by the same observer (W.W.G.).

#### FINDINGS

The means, standard errors, and the P-values of each of the various measurements are listed separately for each sex and age-group in tables 2A and 2B. We included in each annual age-group all children who were not more than six months older or six months younger than the age assigned to the group. For example, the 6-year-old group includes all children who were between  $5\frac{1}{2}$  and  $6\frac{1}{2}$  years of age.

The most comprehensive source of anthropometric data on the children of Japan is an annual publication of the Japanese Ministry of Education which contains the average measurements of school children as determined each year throughout the country. The latest volume of that publication which was available to us is based on data collected in 1953, and these were used (after having been modified as described below) to compare with our measurements of the American-born Japanese children.

The range of the age-groups into which the data are divided in the Japanese report is somewhat different from that of ours. As mentioned above, the median age of the children in each of our age-groups is the age assigned to that group. For example, our 6-year-old age-group includes all children studied who were between  $5\frac{1}{2}$  and  $6\frac{1}{2}$  years old, while in the Japanese report, the 6-year-old group includes all children between 6 years, one day, and 7 years of age. In order to make the two groups of data directly comparable, it was necessary to adjust the Japanese data by graphic interpolation. The Japanese data in their original form and the corresponding interpolated values are given in tables 3A and 3B.

*Standing height, sitting height, and weight*

In order to facilitate further the comparison of the average standing height, sitting height, and weight of the American-born and the native Japanese children, those values are presented graphically in figs. 2, 3, and 4, respectively. The same figures show also the corresponding anthropometric data derived from the Brush Foundation Study of the growth and development of a group of well-circumstanced Caucasian children in Cleveland, Ohio, (Simmons, '44). These Cleveland data together with the corresponding average measurements of the American-born Japanese children are listed numerically in table 4. We shall consider, first, the observed differences between the native Japanese children and those born and reared in the United States, and then comment on some of the similarities and differences between the latter group and the Cleveland children.

It will be noted that at every age the American-born Japanese children exceeded the children of Japan in standing height, sitting height, and in weight. As shown in tables 2A and 2B, all of these differences were statistically significant, with the exception of the standing and sitting heights of the 18-year-old girls.

In general, the American-born Japanese children resembled the Caucasian children in weight somewhat more closely than

TABLE 2A  
*Anthropometric data on American-born Japanese children*

## B O Y S

C.A. GROUP	STATURE (CM)			SITTING HEIGHT (CM)			SITTING HT. RATIO STANDING HT.		WEIGHT (KG)			
	Mean	S.E.	P <sub>1</sub> *	P <sub>2</sub> †	Mean	S.E.	P <sub>1</sub> *	P <sub>2</sub> †	Mean	S.E.	P <sub>1</sub> *	P <sub>2</sub> †
5	108.4	1.07	—	>.05	62.2	0.60	—	>.05	19.6	0.69	—	>.05
6	112.4	0.53	<.01	<.01	63.8	0.28	<.01	<.01	20.6	0.33	<.01	<.01
7	117.8	0.69	<.01	<.01	66.2	0.40	<.01	<.01	23.7	0.64	<.01	>.05
8	124.1	0.98	<.01	<.01	68.8	0.46	<.01	<.01	27.1	0.78	<.01	>.05
9	128.9	0.90	<.01	<.01	71.0	0.56	<.01	.02	30.7	1.42	<.01	>.05
10	132.0	0.89	<.01	<.01	72.1	0.45	<.01	<.01	30.9	1.41	<.01	<.01
11	140.2	1.16	<.01	<.01	76.1	0.58	<.01	>.05	36.4	1.03	<.01	<.05
12	145.9	1.61	<.01	<.01	78.3	0.84	<.01	>.05	40.2	1.76	<.01	>.05
13	153.4	1.55	<.01	.01	82.0	0.80	<.01	>.05	48.1	1.50	<.01	>.05
14	159.3	1.31	<.01	<.01	85.3	0.77	<.01	>.05	50.9	1.57	<.01	>.05
15	164.5	1.44	<.01	<.01	88.5	0.85	<.01	>.05	57.7	1.93	<.01	>.05
16	167.5	1.28	<.01	<.01	91.0	0.58	<.01	>.05	63.5	2.20	<.01	>.05
17	166.7	1.00	<.01	<.01	90.6	0.53	<.01	>.05	63.3	2.11	<.01	>.05
18	169.2	1.28	<.01	—	91.6	0.61	<.01	—	66.4	2.42	<.01	—
Total			<.01	<.01			<.01	>.05			<.01	>.05

\* P<sub>1</sub>= Probability that an equivalent sample could be drawn from the native-born Japanese population.

† P<sub>2</sub>= Probability that an equivalent sample could be drawn from the Brush Foundation Series.

TABLE 2B  
*Anthropometric data on American-born Japanese children*

## GIRLS

C.A. GROUP	STATURE (CM)			SITTING HEIGHT (CM)			SITTING HT. RATIO STANDING HT.		WEIGHT (KG)			
	Mean	S.E.	P <sub>1</sub> <sup>*</sup>	P <sub>2</sub> <sup>†</sup>	Mean	S.E.	P <sub>1</sub> <sup>*</sup>	P <sub>2</sub> <sup>†</sup>	Mean	S.E.	P <sub>1</sub> <sup>*</sup>	P <sub>2</sub> <sup>†</sup>
5	105.8	1.17	—	<.01	60.3	0.55	—	<.01	17.7	0.53	—	.01
6	110.9	0.60	<.01	<.01	62.7	0.35	<.01	<.01	19.7	0.43	<.01	<.01
7	118.5	0.68	<.01	<.01	66.0	0.42	<.01	<.01	23.2	0.52	<.01	<.01
8	123.6	0.81	<.01	<.01	68.6	0.48	<.01	.02	26.6	0.84	<.01	>.05
9	127.0	0.91	<.01	<.01	69.5	0.53	<.01	<.01	27.4	0.87	<.01	<.01
10	134.2	0.87	<.01	<.01	73.0	0.45	<.01	.02	32.3	0.84	<.01	<.01
11	139.8	1.07	<.01	<.01	75.9	0.80	<.01	>.05	37.9	1.72	<.01	>.05
12	145.2	1.24	<.01	<.01	78.6	0.71	<.01	.05	40.0	1.37	<.01	<.01
13	150.5	1.25	<.01	<.01	82.5	0.70	<.01	>.05	47.7	1.38	<.01	>.05
14	152.9	1.29	<.01	<.01	84.2	0.75	<.01	.02	46.9	1.54	<.01	<.01
15	155.3	0.91	<.01	<.01	85.2	0.50	<.01	<.01	51.4	1.24	<.01	<.01
16	154.5	0.95	<.01	<.01	85.5	0.49	<.01	<.01	52.1	1.25	<.01	<.01
17	154.8	0.98	.03	<.01	85.4	0.47	.02	<.01	52.4	1.16	<.01	<.01
18	154.2	1.03	>.05	—	85.4	0.61	>.05	—	52.1	0.97	<.02	—
Total			<.01	<.01			<.01	<.01			<.01	<.01

\* P<sub>1</sub> = Probability that an equivalent sample could be drawn from the native-born Japanese population.

† P<sub>2</sub> = Probability that an equivalent sample could be drawn from the Brush Foundation Series.



TABLE 3A  
*Anthropometric data on children in Japan*  
 Official Japanese data, 1953

## BOYS

AGE IN YEARS	NO. OF CHILDREN	AVERAGE STATURE		AVERAGE SITTING HT.		RATIO SIT. ST.	AVERAGE WEIGHT	
		Mean	S.D.	Mean	S.D.		Mean	S.D.
6½	82,304	109.5	4.6	62.5	2.7	.571	18.6	2.0
7½	58,790	114.8	4.8	65.0	2.8	.566	20.6	2.3
8½	74,431	119.7	5.8	67.2	2.8	.561	22.8	2.5
9½	83,108	124.2	5.2	69.2	2.9	.557	24.8	2.8
10½	79,957	128.7	5.4	71.2	3.0	.553	27.1	3.1
11½	84,373	133.1	5.8	73.0	3.1	.548	29.5	3.6
12½	113,237	137.9	6.5	75.1	3.6	.545	32.5	4.6
13½	102,435	143.5	7.6	77.8	4.3	.542	36.5	5.7
14½	93,467	149.9	8.0	81.0	4.7	.540	41.6	6.7
15½	140,939	157.6	6.9	85.3	4.2	.541	48.1	6.4
16½	138,483	160.9	6.0	87.3	3.8	.543	51.6	6.1
17½	131,070	162.9	5.6	88.8	3.5	.545	54.0	5.8
18½	28,865	162.6	5.6	88.5	3.6	.544	54.7	5.6
19½	8,746	162.5	5.6	88.4	3.5	.544	55.1	5.5

## Interpolated values

		S.E.		S.E.			S.E.	
6	$\sqrt{N} = 287$	107.0	.02	61.2	.009	.574	17.5	.007
7	242	112.1	.02	63.7	.012	.569	19.6	.010
8	273	117.4	.02	66.1	.010	.564	21.6	.009
9	288	122.0	.02	68.2	.010	.559	23.8	.010
10	283	126.5	.02	70.2	.011	.555	26.0	.011
11	291	130.8	.02	72.0	.011	.551	28.4	.012
12	336	135.5	.02	74.0	.011	.547	31.0	.014
13	319	140.5	.02	76.4	.013	.544	34.5	.018
14	306	146.5	.02	79.3	.015	.541	39.0	.021
15	375	153.6	.02	83.0	.011	.541	44.9	.023
16	371	159.3	.02	86.2	.010	.542	49.9	.016
17	362	162.0	.02	88.0	.010	.544	52.8	.016
18	170	162.8	.03	88.7	.021	.545	54.4	.033
19	94	163.6	.06	89.7	.06			

*Anthropometric data on children in Japan*

Official Japanese data, 1953

## G I R L S

AGE IN YEARS	NO. OF CHILDREN	AVERAGE STATURE		AVERAGE SITTING HT.		RATIO SIT. ST.	AVERAGE WEIGHT	
		Mean	S.D.	Mean	S.D.		Mean	S.D.
6½	78,673	108.6	4.5	62.0	2.7	.571	18.0	2.0
7½	57,273	114.0	4.8	64.6	2.7	.567	20.1	2.3
8½	72,428	118.8	5.0	66.8	2.8	.562	22.1	2.6
9½	81,199	123.5	5.3	68.9	3.0	.558	24.3	2.9
10½	77,588	128.3	5.8	71.1	3.2	.554	26.8	3.4
11½	81,578	133.6	6.3	73.6	3.5	.551	29.9	4.3
12½	109,602	139.4	6.7	76.5	4.0	.549	34.1	5.3
13½	99,166	144.2	6.5	79.1	3.9	.549	38.3	5.8
14½	91,034	148.0	6.0	81.3	3.6	.549	42.5	5.8
15½	110,177	151.3	5.0	83.3	3.0	.551	46.3	5.5
16½	104,577	152.3	4.8	84.0	2.9	.552	48.4	5.5
17½	94,025	153.0	4.9	84.4	3.0	.552	49.5	5.4
18½	11,898	152.7	4.9	84.1	2.9	.551	50.0	5.3
19½	1,759	152.6	5.1	84.0	3.1	.550	50.4	5.5

## Interpolated values

	N	S.E.		S.E.			S.E.	
		Mean	S.D.	Mean	S.D.		Mean	S.D.
6	280	105.6	.016	60.8	.010	.573	16.8	.007
7	239	111.0	.020	63.4	.011	.569	19.0	.010
8	269	116.3	.019	65.8	.010	.563	21.0	.010
9	285	121.0	.019	68.0	.011	.560	23.1	.010
10	279	125.7	.021	70.0	.011	.556	25.5	.012
11	286	130.9	.022	72.2	.012	.553	28.3	.015
12	331	136.4	.020	75.0	.012	.550	31.9	.016
13	315	141.7	.021	77.6	.012	.549	36.0	.018
14	362	146.1	.020	80.0	.012	.549	40.0	.019
15	332	149.6	.015	82.2	.009	.550	44.1	.017
16	323	151.9	.015	83.5	.009	.552	47.2	.017
17	307	152.7	.016	84.2	.010	.552	49.0	.018
18	109	152.9	.045	84.3	.027	.552	49.8	.049
19	42	152.7	.122	84.1	.074	.551	50.2	.131

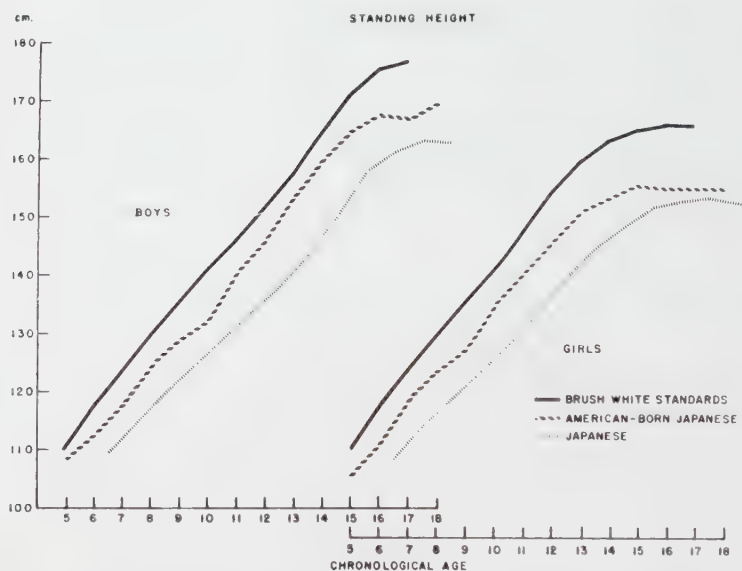


Fig. 2 The average standing height of the American-born Japanese, native Japanese, and Cleveland White children at successive chronological ages.

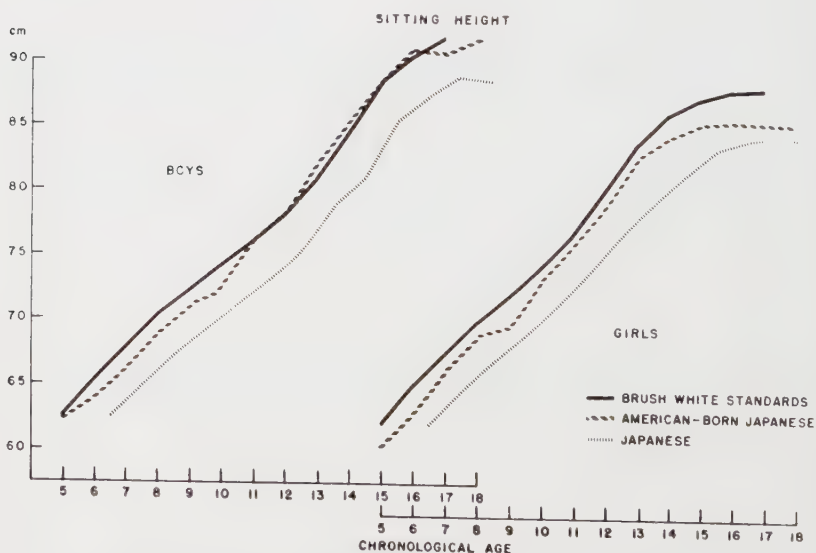


Fig. 3 The average sitting height of American-born Japanese, native Japanese, and Cleveland White children at successive chronological ages.

they did in height. Despite their smaller stature, the American-born Japanese boys equalled or closely approached the Cleveland White boys in weight from 5 to 9 years and again at 13 and 16 years. The girls of the former group, however, remained somewhat lighter than the Cleveland girls throughout the age period considered in our study.

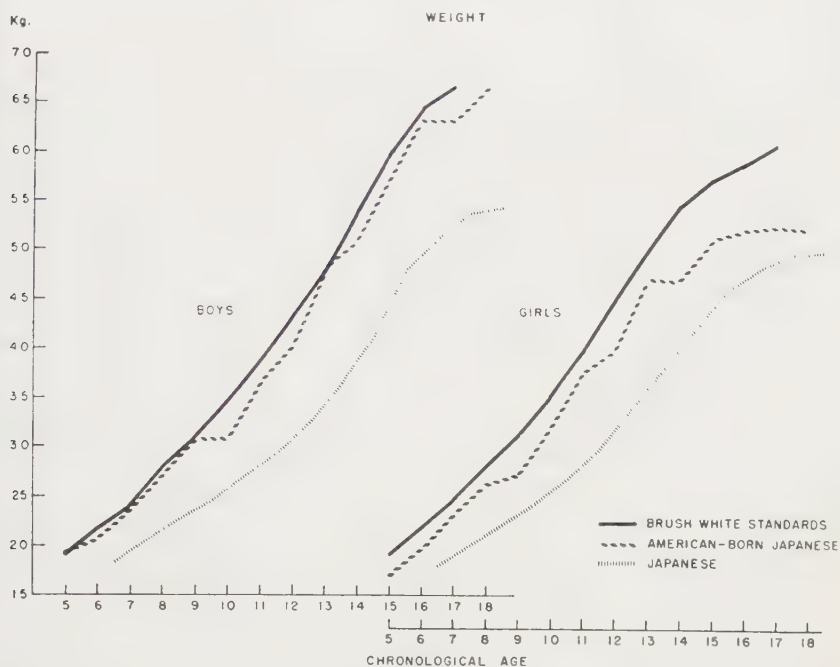


Fig. 4 The average weight of American-born Japanese, native Japanese, and Cleveland White children at successive chronological ages.

While certain aspects of sitting height are more clearly expressed in the sitting height/standing height ratios shown in figure 3 and in tables 2 and 3, the observed sitting heights themselves deserve at least a passing comment.

As mentioned earlier, the sitting height of the American-born Japanese children exceeded that of the children in Japan at every age covered in this study. This, of course, is not surprising, in view of the greater stature of the California group. Despite the fact that they were shorter than the Cau-

TABLE 4  
*Anthropometric data on American-born Japanese and Brush Foundation children*

AGE IN YEARS	STANDING HEIGHT		SITTING HEIGHT		SITTING HT. RATIO		WEIGHT	
	Japanese- American 1957	Brush Foundation Children 1931-42	Japanese- American 1957	Brush Foundation Children 1931-42	Japanese- American 1957	Brush Foundation Children 1931-42	Japanese- American 1957	Brush Foundation Children 1931-42
BOYS								
5	108.4	110.7	62.2	62.6	57.4	56.5	19.6	19.4
6	112.4	117.7	63.8	65.4	56.8	55.6	20.6	21.9
7	117.8	123.8	66.2	67.7	56.1	54.7	23.7	24.6
8	124.1	129.9	68.8	70.3	55.4	54.1	27.1	28.0
9	128.9	135.4	71.0	72.4	55.0	53.5	30.7	31.0
10	132.0	141.0	72.1	74.3	54.6	52.7	30.9	34.9
11	140.2	145.9	76.1	76.2	54.3	52.2	36.4	38.8
12	145.9	151.4	78.3	78.3	53.7	51.7	40.2	43.2
13	153.4	157.5	82.0	80.8	53.5	51.3	48.1	47.9
14	159.3	164.8	85.3	84.6	53.5	51.3	50.9	54.0
15	164.5	171.1	88.5	88.6	53.8	51.7	57.7	60.0
16	167.5	175.2	91.0	90.4	54.4	51.6	63.5	64.4
17	166.7	176.6	90.6	91.8	54.4	52.0	63.3	66.9
18	169.2	—	91.6	—	54.1	—	66.4	—
GIRLS								
5	105.8	110.6	60.3	62.2	57.0	56.2	17.7	19.1
6	110.9	117.6	62.7	65.1	56.5	55.4	19.7	21.9
7	118.5	123.8	66.0	67.5	55.7	54.5	23.2	24.7
8	123.6	129.8	68.6	69.8	55.5	53.8	26.6	28.1
9	127.0	135.3	69.5	71.9	54.7	53.1	27.4	31.6
10	134.2	141.0	73.0	74.2	54.4	52.6	27.4	35.4
11	139.8	147.7	75.9	76.9	54.3	52.1	37.9	40.1
12	145.2	154.2	78.6	80.1	54.2	51.9	40.0	45.6
13	150.5	159.5	82.5	83.6	54.8	52.4	47.7	50.1
14	152.9	162.9	84.2	86.1	55.1	52.8	46.9	54.5
15	155.3	164.8	85.2	87.3	54.9	53.0	51.4	57.4
16	154.5	165.5	85.5	87.9	55.3	53.1	52.1	58.9
17	154.8	165.4	85.4	88.0	55.2	53.2	52.4	60.9
18	158.1	—	88.1	—	55.2	—	58.9	—



casian children in the Cleveland study, they resembled them rather closely in sitting height. In fact, the sitting height of the American-born Japanese boys equalled or exceeded that of the Cleveland children of the same sex from 11 through 15 years of age. The American-born Japanese girls, though never quite equalling the Cleveland girls in sitting height, approached them in that dimension somewhat more closely than they did in stature.

Up to about 15 years of age in the boys and 13 years in the girls, the American-born Japanese children were found to be relatively longer-legged than the children of the same sex and age in Japan. However, the sitting height/standing height ratios of the older children (except that of the 18-year-old boys) resembled very closely the corresponding ratios of the children in Japan.

The relatively greater sitting height of the American-born Japanese children as compared with the Cleveland children is apparent in figure 3. It is even more clearly seen, however, in figure 5, in which the sitting height/standing height ratios of the American-born and the native Japanese children can be compared with each other and with those of the Caucasian children.

It is interesting to note that the increase in the sitting height/standing height ratios of the American-born Japanese girls occurred between 12 and 13 years, as it did in the Cleveland girls. There is some suggestion that there is a comparable similarity in the age at which the spurt of growth in trunk length occurred in the boys of the same two groups.

#### *Skeletal development*

The most extensive study of the skeletal development of healthy children in Japan is that reported by Sutow ('53). His report is based on a study of radiographs of the hand and wrist of boys and girls in Hiroshima who were used as controls in the Atomic Bomb Casualty Commission's study of children who survived the atomic bombing of that city. The children of the control series had come to Hiroshima after the

war and, presumably, had not been exposed to any of the radiation attributable to the bombing. On the basis of his findings, Sutow and Ohwada ('53) constructed a set of standards which portray the representative stage of skeletal development attained by the boys and by the girls of the control series at successive annual intervals from 6 to 19 years. He subse-

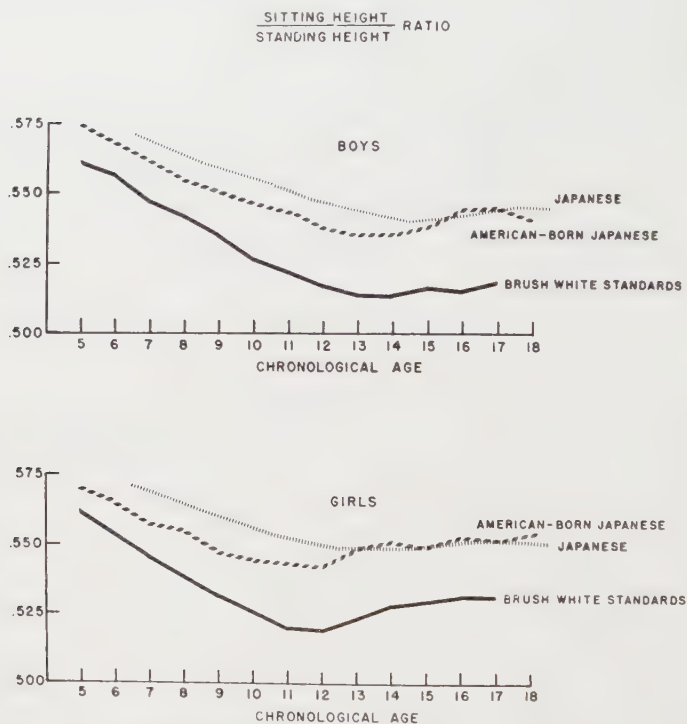


Fig. 5 The sitting height/standing height ratio of American-born Japanese, native Japanese, and Cleveland White children at successive chronological ages.

quently assessed each of his standards by the Greulich-Pyle standards, which are based on the rate of skeletal development of the Cleveland children referred to earlier in this paper.

The magnitude of the differences between the skeletal status of native Japanese and the Caucasian children on whom the Greulich-Pyle standards are based can be seen in table 5. The skeletal development of the Japanese boys and girls is less advanced than that of the Caucasian children at every age in-

cluded in Sutow's standards. Their relative retardation ranged from 6 to 24 months in boys and from 9 to 24 months in girls.

Since each of Sutow's standards depicts the skeletal status of the hand and wrist which he considered most representative of that age and sex among the children of the Hiroshima con-

TABLE 5

*Comparison of Sutow's Hiroshima standards with the Greulich-Pyle standards*

SUTOW	GREULICH-PYLE		DIFFERENCE (in months)
Years	Years	Months	
B O Y S			
6	4	6	18
7	5	3	21
8	7		12
9	7	10	14
10	8	9	15
11	9		24
12	11		12
13	12	6	6
14	12	9	15
15	14		12
16	14	6	18
17	16		12
18	17		12
19	18	2	10
G I R L S			
6	4	3	21
7	6	3	9
8	6	10	14
9	7	9	15
10	9		12
11	10		12
12	10	9	15
13	11		24
14	12	6	18
15	13	6	18
16	14	6	18
17	15		24
18	17		12
19	17		24

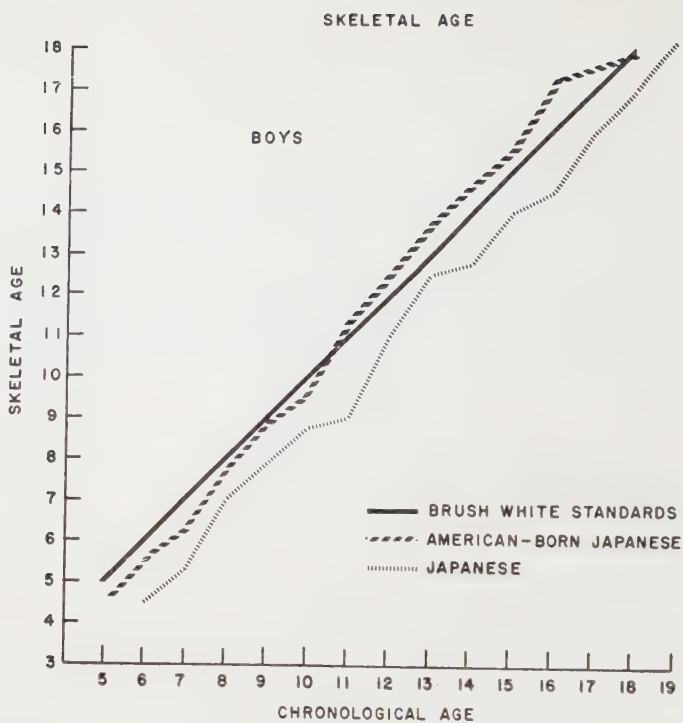


Fig. 6 The average skeletal age of American-born Japanese, native Japanese, and Cleveland White boys at successive chronological ages.

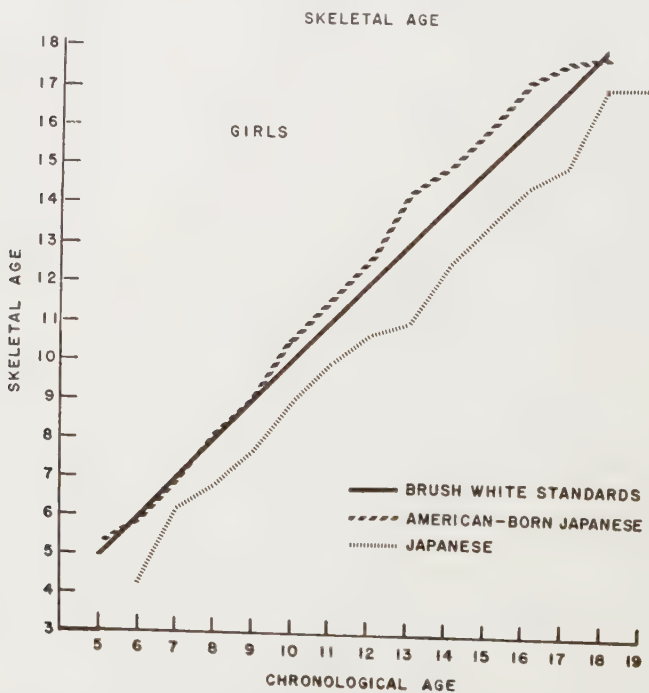


Fig. 7 The average skeletal age of American-born Japanese, native Japanese, and Cleveland White girls at successive chronological ages.

trol series, we have used his assessments of those standards to compare with the skeletal status of the American-born Japanese children of the same sex and age. This was possible, because both Sutow's standards and the hand films of the American-born Japanese children were assessed by the Greu-

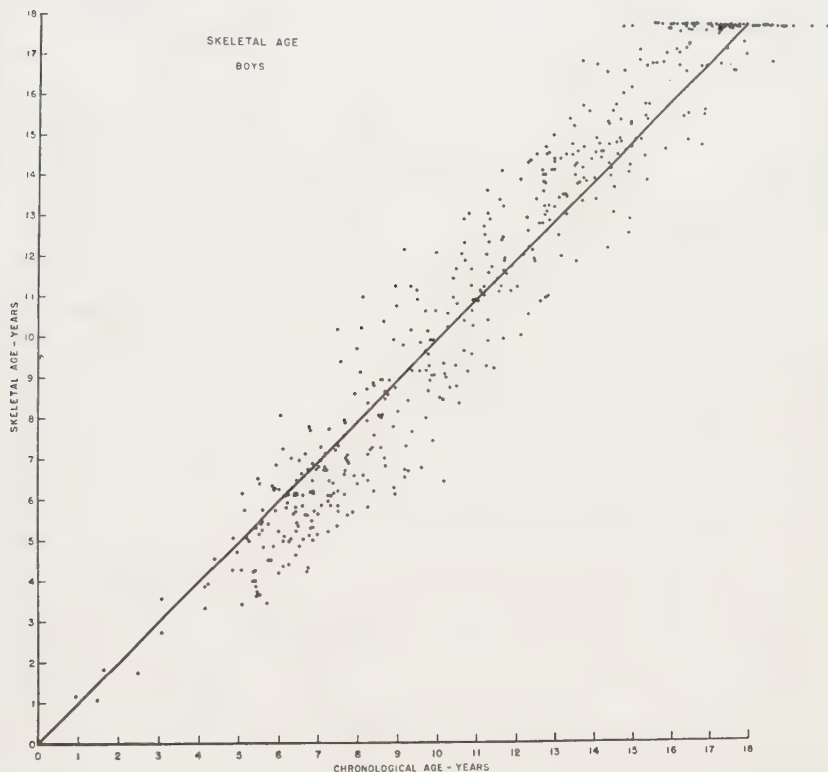


Fig. 8 Scatter-diagram showing the average skeletal age of individual American-born Japanese boys as assessed by the Greulich-Pyle standard, which is represented by the diagonal line in the graph.

lich-Pyle standards and are, therefore, directly comparable. The fact that substantially the same method was used in constructing both sets of standards contributes further to their comparability.

Figures 6 and 7 show the average skeletal age of both the American-born and the native Japanese children throughout



the age range covered in the two studies. Included in each figure is a diagonal line representing the rate of skeletal development of the Cleveland children on whom the Greulich-Pyle standards are based. The two scatter-diagrams, figures

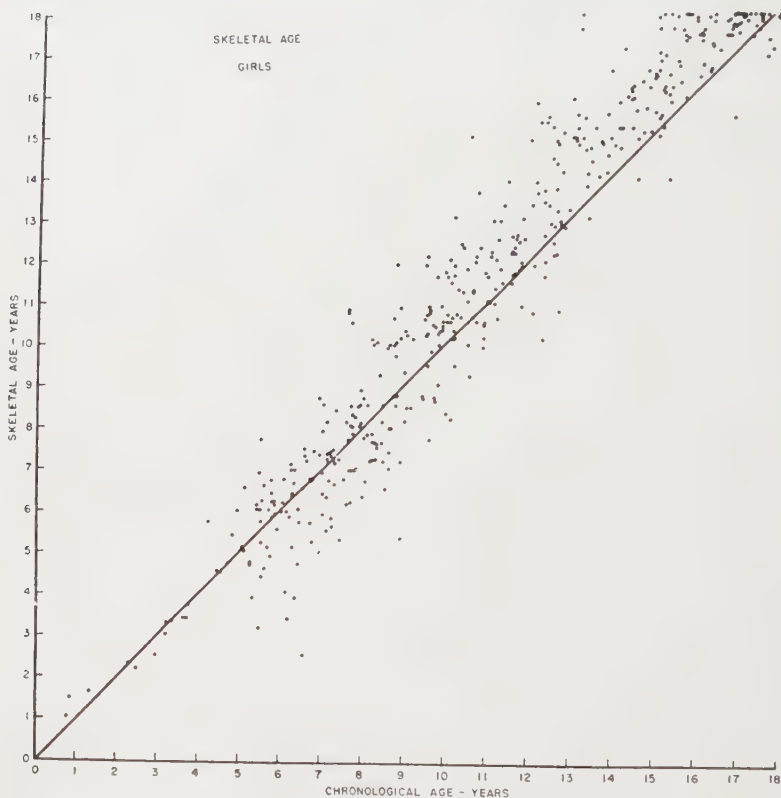


Fig. 9 Scatter-diagram showing the average skeletal age of individual American-born Japanese girls as assessed by the Greulich-Pyle standard, which is represented by the diagonal line in the graph.

8 and 9, which are based on some of the same data as figures 6 and 7, are included here, because they provide a somewhat clearer idea than do the corresponding mean values of how the skeletal ages of the individual California Japanese children compared with those of representative Caucasian children of the same sex and chronological age.

C.A. GROUP	SKELETAL AGE		P <sub>1</sub> *	P <sub>2</sub> †	S.A. - C.A.		S.A. - C.A.		
	Mean	S.E.			Years		%		
					Mean	S.E.	Mean	S.E.	
BOYS									
5	4.64	.21	<.01	<.01	—	.59	—	11.0	4.2
6	5.58	.13	<.01	<.01	—	.45	—	7.4	2.2
7	6.26	.14	<.01	<.01	—	.72	—	10.4	1.9
8	7.65	.24	>.05	>.05	—	.35	—	4.3	2.9
9	8.79	.29	.02	>	—	.18	—	2.1	3.1
10	9.56	.22	<.01	.05	—	.41	—	4.2	2.1
11	11.34	.21	<.01	>.05	—	.32	—	2.9	1.9
12	12.39	.23	<.01	>.05	—	.41	—	3.4	1.9
13	13.63	.19	<.01	<.01	—	.65	—	4.9	1.4
14	14.61	.19	<.01	<.01	—	.61	—	4.4	1.4
15	15.54	.23	<.01	<.01	—	.58	—	3.9	1.5
16	17.24	.19	<.01	<.01	—	1.17	—	6.8	1.4
17	17.55	.15	<.01	<.01	—	.54	—	3.2	0.9
18	17.83	.08	<.01	>.05	—	.04	—	1.0	0.4
Total			<.01	>.05	—	.08	—	1.0	0.6
GIRLS									
5	5.39	.25	<.01	>.05	—	.26	—	5.0	4.4
6	5.85	.16	<.01	>.05	—	.13	—	1.9	2.8
7	6.98	.15	<.01	>.05	—	.08	—	0.1	2.3
8	8.11	.18	<.01	>.05	—	.12	—	1.5	2.3
9	8.99	.27	<.01	>.05	—	.11	—	1.2	2.9
10	10.61	.16	<.01	<.01	—	.64	—	6.6	1.6
11	11.59	.21	<.01	<.01	—	.61	—	5.5	1.9
12	12.62	.23	<.01	<.01	—	.62	—	5.1	1.8
13	14.32	.25	<.01	<.01	—	1.38	—	10.6	1.8
14	14.98	.20	<.01	<.01	—	1.00	—	7.1	1.2
15	16.08	.16	<.01	<.01	—	1.00	—	6.6	1.0
16	17.13	.15	<.01	<.01	—	1.16	—	7.5	0.9
17	17.65	.10	<.01	<.01	—	.65	—	3.8	0.6
18	17.78	.07	<.01	>.05	—	0	—	0	0.4
Total			<.01	<.01	—	.52	—	4.2	0.6

\* P<sub>1</sub> = Probability that an equivalent sample could be drawn from the native-born Japanese population.

† P<sub>2</sub> = Probability that an equivalent sample could be drawn from the Brush Foundation Series.

As shown in table 6 and in figures 6-9, the skeletal development of the American-born Japanese children was found to be more advanced than that of the children of the same sex and age in Japan, and the difference is statistically significant for every age group of both sexes, except the 8-year-old boys.

The skeletal age of the American-born Japanese boys was significantly lower than that of the Cleveland White boys at 5, 6, and 7 years, but it was significantly higher than that of the latter group at 13, 14, 15, 16, and 17 years. There was no statistically significant difference between the two groups of boys at the other ages. The American-born Japanese girls were significantly advanced in their skeletal development as compared with the Cleveland girls from 10 to 17 years of age. There was no significant difference in the skeletal status of the two groups of girls at the other ages for which data were available.

#### DISCUSSION

A gradual increase in stature over the years has been observed in various countries. A consideration of the increase which has occurred in the stature of the children of Japan during the past half-century will enable us to evaluate somewhat more meaningfully the difference which we found to exist between the stature of present-day children in Japan and that of those of Japanese ancestry in California. Figures 10 and 11 show graphically the average standing height of school children in Japan in 1900 and in 1953 and the corresponding values for the California children in 1956-57. The same data are listed numerically in table 7.

It is interesting to note that, at every age, the American-born Japanese boys exceeded in average stature the boys of Japan in 1953 by an amount greater than the increase which had taken place in the stature of the boys in Japan during the preceding 53 years. The same is true of the American-born Japanese girls from 6 through 14 years of age. The superiority in average stature of the 15, 16, and 17-year-old California girls as compared with those of the same age in Japan is, however, somewhat less than the amount which girls of those

ages in Japan gained in average stature between 1900 and 1953. During the same period, the 18-year-old Japanese girls gained 0.5 cm more in average stature than the amount by which the American-born girls exceeded them in that dimension in 1956-57.

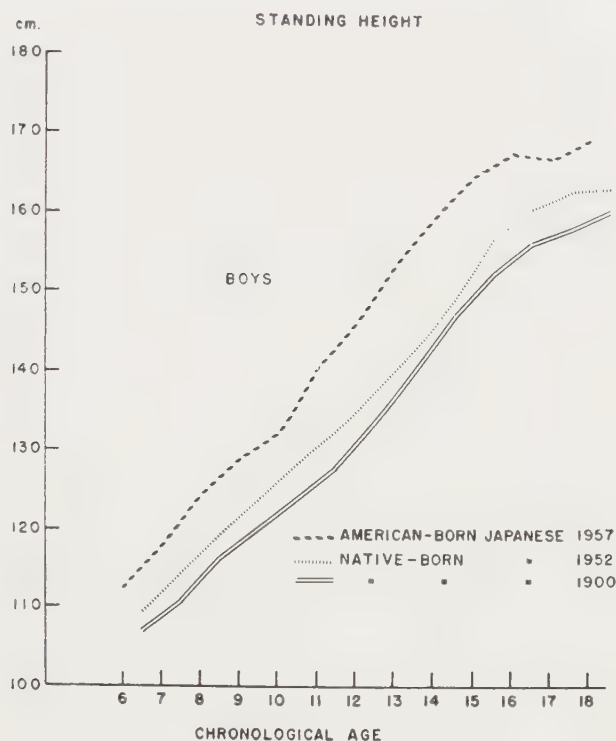


Fig. 10 The difference in average standing height between the American-born and the native Japanese boys compared with the increase which has taken place in the stature of boys in Japan since 1900.

A possible explanation of this difference may lie in the different rate at which the average adult stature of the two sexes increased in Japan since the beginning of the present century. Between 1900 and 1952,<sup>2</sup> the average stature of 20-year-old males changed from 160.9 to 164.7 cm, a gain of

<sup>2</sup> Data on the stature of 20-year-old males and females in 1953 were not available to us.

3.8 cm. During the same period, the 19-year-old females (who should, in general, be comparable to the 20-year-old males) increased 6.4 cm in average stature, i.e., from 147.0 cm to 153.4 cm. When the gain of each sex is expressed as a percentage of its stature in 1900, it is found to be an increase of 2.4% in the males, as compared with 4.4% in the females.<sup>3</sup>

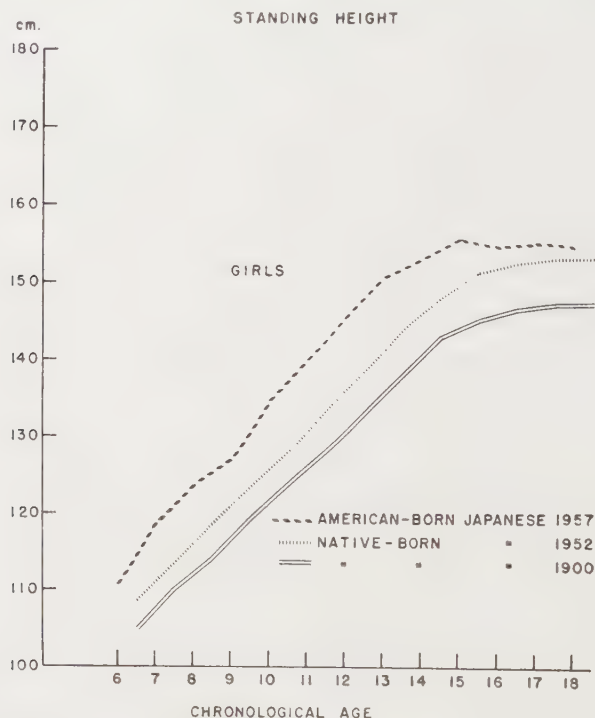


Fig. 11 The difference in average standing height between the American-born and the native Japanese girls compared with the increase which has taken place in stature of girls in Japan since 1900.

This suggests that the males responded less readily than did the females to the improvement in nutrition and to the other factors responsible for their progressive increase in

<sup>3</sup> If the same comparison is made between 20-year-old males and 20-year-old females, it is found that the latter increased from 147.9 in 1900 to 153.7 in 1952, i.e. 5.8 cm or 3.9%.



bodily dimensions over this 52 year period. It seems probable that, as a result, the females during the period from 1900 to 1952 achieved a greater part of their full growth potential than did the males, whose present superior growth rate may represent a continuing effort to achieve theirs.

TABLE 7

*The difference in average stature between American-born and native Japanese children compared with the increase in average stature in the latter group since 1900*

AGE IN YEARS	JAPANESE- AMERICAN 1957	JAPANESE 1953 INTERPOLATED	DIFFERENCE	JAPANESE 1953 (original form)	JAPANESE 1900 (original form)	DIFFERENCE
B O Y S						
6	112.4	107.0	5.4	109.5	107.0	2.5
7	117.8	112.1	5.7	114.8	110.9	3.9
8	124.1	117.4	6.7	119.7	116.1	3.6
9	128.9	122.0	6.9	124.2	120.0	4.2
10	132.0	126.5	5.5	128.7	123.9	4.8
11	140.2	130.8	9.4	133.1	127.9	5.2
12	145.9	135.5	10.4	137.9	133.9	4.0
13	153.4	140.5	12.9	143.5	140.0	3.5
14	159.3	146.5	12.8	149.9	147.0	2.9
15	164.5	153.6	10.9	157.6	152.1	5.5
16	167.5	159.3	8.2	160.9	156.1	4.8
17	166.7	162.0	4.7	162.9	157.9	5.0
18	169.2	162.8	6.4	162.6	160.0	2.6
G I R L S						
6	110.9	105.6	5.3	108.6	104.8	3.8
7	118.5	111.0	7.5	114.0	110.0	4.0
8	123.6	116.3	7.3	118.8	113.9	4.9
9	127.0	121.0	6.0	123.5	119.1	4.4
10	134.2	125.7	8.5	128.3	123.9	4.4
11	139.8	130.9	8.9	133.6	127.9	5.7
12	145.2	136.4	8.8	139.4	133.0	6.4
13	150.5	141.7	8.8	144.2	137.9	6.3
14	152.9	146.1	6.8	148.0	143.0	5.0
15	155.3	149.6	5.7	151.3	144.8	6.5
16	154.5	151.9	2.6	152.3	146.1	6.2
17	154.8	152.7	2.1	153.0	147.0	6.0
18	154.2	152.9	1.3	152.7	147.0	5.7

We observed a comparable sexual difference in our study of the children of Guam (Greulich, '51) and of the children who were exposed to the effects of the atomic bombing of Hiroshima and Nagasaki (Greulich, Crismon, and Turner, '53). In those groups, it appeared that the boys withstood less successfully than the girls the rigors of an unfavorable environment and that they required a longer period than did the girls to recover from its deleterious effects.

The present study thus provides additional evidence of the functional superiority of the human female as compared with the male. Whoever, today, continues to regard hers as the "weaker" sex, is permitting either faulty information or prejudice to mislead him.

The question is frequently asked whether or not the increasing stature of successive generations of children in the United States and in some European countries indicates that this process is likely to continue and so result eventually in a population of minor giants. The observed smaller relative increase in the stature of American-born Japanese girls as compared with boys of the same group provides, perhaps, a partial answer to the question. It suggests that, at least, in a racially homogeneous population, this process is self-limiting and that the increase in average stature in successive generations becomes progressively smaller as more and more individuals of the group achieve their full, genetically determined, growth potential.

Quite as remarkable as the magnitude of the difference in stature between the American-born and the native Japanese children is the difference in the standing height/sitting height ratios between the two groups, which appears to be attributable to the greater momentum of growth during the early childhood and pre-puberal periods in the American-born Japanese children.

The relatively longer legs of the American-born Japanese children up to about the time of puberty illustrate how good nutrition and other favorable environmental factors can affect a feature which is usually considered to be a racial character

and, therefore, genetically determined and controlled. The real racial character here appears to be the sitting height/standing height ratio of the *adult*, which will probably not be appreciably different in the American-born and the native Japanese children when their growth is completed.

Sutow ('53) suggested that the relative skeletal retardation which he found at every age among the Hiroshima children might be due, at least in part, to some racial difference between the skeletal development of Japanese and Caucasian children.

As pointed out above, the skeletal age of the California Japanese children was significantly less than that of the Cleveland White children only in the case of the 5, 6, and 7-year-old boys. Even the boys were significantly more advanced in their skeletal development than the Cleveland boys at 13, 14, 15, 16, and 17 years and they did not differ significantly from them during the period from 8 to 12 years of age. The Japanese girls were significantly more advanced skeletally than the White girls from 10 to 17 years of age and they did not differ significantly from them at any other ages.

Our comparison of the skeletal status of the American-born Japanese children with that of the Cleveland children does not support the assumption that the Japanese as a group are retarded in their skeletal development as compared with the Whites. On the contrary, the California Japanese children were found to be significantly more advanced than the latter group during the post-puberal and early adolescent years. The marked retardation in the skeletal development of the Hiroshima children would, therefore, appear to be attributable to the less favorable nutritional and other environmental conditions under which they were reared.

#### SUMMARY

The physical growth and developmental statuses of 898 American-born Japanese children living in the San Francisco Bay area of California was compared with those of children of the same sex and age in Japan.

The California Japanese children were found to be taller, heavier, more advanced skeletally, and, during the pre-puberal period, distinctly longer-legged than the children in Japan. During early adolescence, however, the sitting height/standing height ratios of the American-born Japanese came to be indistinguishable from those of the native Japanese of the same sex and age.

At every age considered in the study, the American-born Japanese boys were found to exceed in stature the boys of present-day Japan by an amount greater than the increase which had taken place in the stature of the boys in that country during the preceding 53 years. A similar superiority in stature was shown by the American-born Japanese girls, but only from 6 to 14 years of age. At 15, 16, and 17 years, their superiority in stature was somewhat less than the amount which the girls of those ages in Japan had gained in average stature between 1900 and 1953. During the same period, the 18-year-old Japanese girls gained 0.5 cm more in average stature than the amount by which the American-born Japanese girls exceeded them in that dimension in 1956-57.

This difference may have its basis in the different rate at which the average stature of the two sexes increased in Japan since the beginning of the present century. Between 1900 and 1952, the average stature of the 20-year-old males increased by only 2.4%, while that of the comparable females increased by 4.4%. This is interpreted as indicating that, since the beginning of the present century, the females achieved a greater part of their full growth potential than did the males, whose current superior growth rate is an evidence of their continuing progress towards the same goal.

The skeletal status of the American-born Japanese children was found to be very similar to that of the Cleveland White children on whom the Greulich-Pyle standards of skeletal development are based. This observation does not support the view that the relative retardation in skeletal development of the Hiroshima children reported by Sutow (4) is attributable to some racial difference between Japanese and Caucasians.

It is believed to be due, rather, to a more limited diet and to other less favorable environmental conditions existing in Japan.

---

Throughout the course of this study, I have had the benefit of the very helpful collaboration of my associates, Cathrine S. Crismon, Mildred L. Greulich, and Yoshio Okumoto. It is a pleasure to acknowledge here my indebtedness to them and to Professor Charles Haskell Danforth for his critical reading of the manuscript.

#### LITERATURE CITED

- GREULICH, W. W. 1951 The growth and developmental status of Guamanian school children in 1947. *Am. J. Phys. Anthropol.*, n.s. 9: 55-70.
- GREULICH, W. W., C. S. CRISMON AND M. L. TURNER 1953 The physical growth and development of children who survived the atomic bombing of Hiroshima or Nagasaki. *J. Pediat.*, 43: 121-145.
- SIMMONS, K. 1944 The Brush Foundation Study of Child Growth and Development. II. Physical Growth and Development. Monograph of the Society for Research in Child Development Vol. 9 National Research Council, Washington, D. C.
- Statistical Report of School Health. MEJ 8676, Ministry of Education, Tokyo, 1952 (p. 23).
- Statistical Report of School Health. MEJ 8687, Ministry of Education, Tokyo, 1953 (pp. 32, 33, and 34).
- SUTOW, W. W. 1953 Skeletal Maturation in healthy Japanese children, 6 to 19 years of age—Comparison with skeletal maturation in American children. *Hiroshima J. of Med. Sciences*, 2: 181-191.
- SUTOW, W. W., AND K. OHWADA 1953 Skeletal standards of healthy Japanese children from age 6 to 19 years. *Clinical Pediatrics (Japanese)*, 6: No. 11.





# THE CHIN REGION OF THE AUSTRALIAN ABORIGINAL MANDIBLE

THOMAS MURPHY

*Department of Anatomy, University of Adelaide, South Australia*

FIVE FIGURES

## INTRODUCTION

As the part of the mandible which forms the chin is a distinctively human characteristic, this region is of exceptional anthropological interest. The literature deals with the labial aspect, the mental foramen, the mental angle and the genial tubercles and foramina in various ethnic groups.

The purpose of this study is to make a record, at present lacking, of these conditions in the Australian aboriginal mandible.

## MATERIAL AND METHODS

Mandibles suitable for examination and measurement in the collections housed in the Department of Anatomy, University of Adelaide, and in the South Australian Museum numbered 625. For some observations all were inspected, for others a lesser number sufficed.

### *Age classification*

As the mandible is a tooth-bearing bone convenient criteria exist for classification in the following groups.

1. Symphysis menti fused but prior to the eruption of the second deciduous molar to its functional position.
2. Second deciduous molar in place but prior to the eruption of the first permanent molar to its functional position.

3. First permanent molar in place but prior to the eruption of the second permanent molar to its functional position.
4. Second permanent molar in place but prior to the eruption of the third permanent molar to its functional position.
5. All teeth in place, no or negligible tooth loss. Senile mandibles with total or extensive tooth loss were excluded from age-incidence studies.

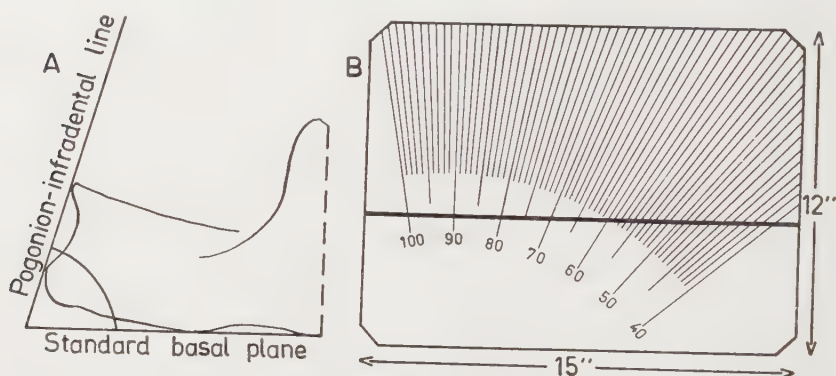


Fig. 1 A — The mental angle, and B — its goniometer.

### *Sex classification*

No attempt was made to differentiate between the sexes in the first four groups. Adult non-senile mandibles numbered 476. Sex was recorded according to anatomical appreciation of the accompanying skull in 386 cases. The remaining 90 were odd and so presented less valid criteria.

In common with other bones the female mandible is smaller, more slender, and has fewer muscular markings than the male. It also has a larger mandibular angle, and an absolutely and relatively smaller condyle (Martin, '36), a smaller coronoid projective height (Hrdlicka, '40), and the angle tends to be inverted in contrast to the everted male angle (Gray, '54, p. 293). While some degree of error in sex determination is inevitable this need not invalidate findings as intermediate specimens fall "within the scope of the interdigitation of the

two sexes," and "affect perceptibly neither one nor the other" (Hrdlicka, '40).

### *Measurement*

The mental angle is defined as the angle formed by the intersection of the standard basal plane and the pogonion-infradental line (fig. 1A). Precise instructions for its measurement using Ranke's goniometer are given by Morant ('36). This method is criticized by Cleaver ('37) and in the present study was found to be laborious and meticulous to a degree out of all proportion to the wide range of the angle. A special goniometer was made by ruling a sheet of celluloid (cleaned 15"  $\times$  12" X-ray film) with an enlarged section of a protractor which included the range of the measurement (fig. 1B). This was done by placing an ordinary protractor in the epidiascope and suitably adjusting the size of the projected image. In use the mandible was placed in profile on an eye-level platform, the horizontal line on the celluloid made to coincide with the platform (and thus the standard basal plane), and the celluloid sheet moved to right or left and the reading taken on the line which was tangential to both the pogonion and the infradental.

### LABIAL ASPECT

#### *The chin proper*

Weidenreich ('04) emphasizes the double nature of the bone formation which forms the mental protuberance as being a mid-line symphyseal tuberosity, and the right and left mental tubercles. Schulz ('33) and Keiter ('35) describe different shapes of this triangular formation and record their findings for various ethnic groups. Keiter's three shapes are Kinnpyramide, Kinnstern, and Kinnwulst. He records the incidence in his series of 33 Australian mandibles as 60.6, 21.2 and 18.2% respectively; and for his 54 Melanesian mandibles as 34.8, 37 and 28.2%.

In the present material the shape was remarkably consistent with a crescentic junction between mental fossae and

mental protuberance and with a crescentic submental notch. The pogonion was rarely depressed and then only slightly. No age, regional or sex differences could be detected. The general shape was maintained regardless of the mental angle.

This shape fits Keiter's "Kinnstern." The differentiation described by the German workers is not evident, and seems valueless as a criterion of ethnic differences.

### *Median canal of the chin*

This feature is usual in some non-human primates. Le Double ('06) records finding it twice in 300 French mandibles, and cites Bertelli as finding it 3 times in 380 Italian, and Dubreuil-Chambardel once in 75 Touraine mandibles. This makes a European incidence of 6 in 755 (0.79%). Augier ('31, p. 509) cites Dubreuil-Chambardel as stating an incidence of 5% "dans la race jaune."

The median canal was lacking in all 625 Australian aboriginal mandibles examined in the present study.

## THE MENTAL FORAMEN

### *Multiplicity*

A survey of the literature indicates that in man the mental foramen is usually single but may be multiple. Multiple foramina usually number two but there may be more.

A preliminary review of the material showed that in multiple mental foramina the accessory foramen may be one of two types. These may conveniently be called the minor and major accessory foramina.

The more common minor accessory foramen lies anteriorly, usually on or just within the sharp rim of the main foramen (fig. 2A), and separated from it by a tongue of bone. Sometimes this tongue is poorly developed so that division of the foramen is not readily observed. At other times the tongue and the general configuration suggest an accessory foramen, and this may or may not become visible with the use of a hand lens. Thus a criterion for presence/absence must be stated.



In this study presence was recorded only if the foramen could be seen with the unaided eye and without peering into the main foramen.

The rarer major accessory foramen, always much larger than the minor, is clearly separate from the main foramen and occupies one of four possible positions relative to it, antero-superior, posterior, postero-superior, or inferior (fig. 2B, C, D, E).

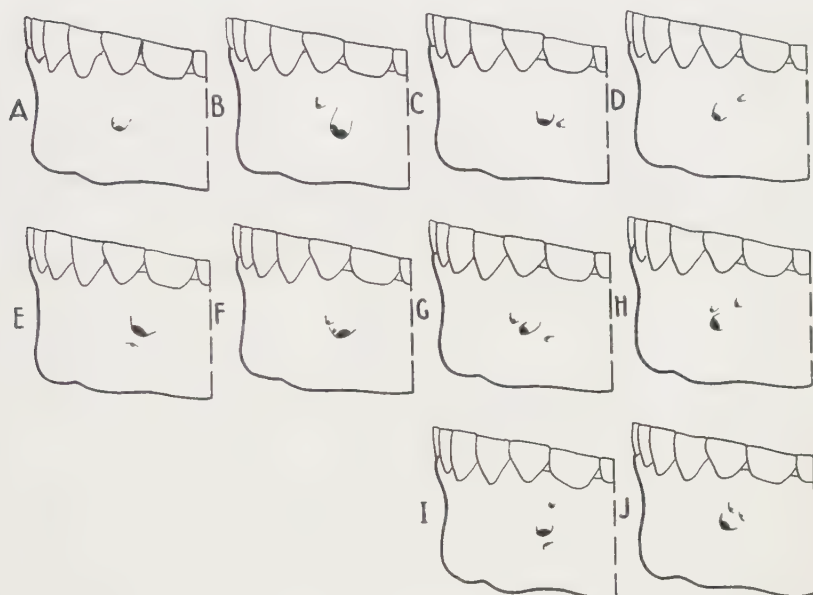


Fig. 2 Types of multiple mental foramen —

Double

- A Minor accessory foramen
- B Major accessory foramen: antero-superior
- C Major accessory foramen: posterior
- D Major accessory foramen: postero-superior
- E Major accessory foramen: inferior

Triple

- F Minor + major: antero-superior
- G Minor + major: posterior
- H Minor + major: postero-superior
- I Major: postero-superior + inferior
- J Major: postero-superior (doubled)

(all illustrated on left side to facilitate comparison)

Triple foramina were formed by combinations (fig. 2F, G, H, I), except in one case which appeared to have a doubled postero-superior major accessory foramen (fig. 2J).

Including senile mandibles 1200 sides were examined. Multiple foramina were observed in 200 (16.7%). Bilateral multiple foramina were present in 48 mandibles. No significant age difference was found. The female adult incidence was 19.2% and the male 12.1%. This sex difference was found to be significant, by chi-square test, at the level  $P < 0.01$ .

The multiple foramen was double 177 times and triple 23 times. No greater number than three foramina was seen. A slightly greater left side incidence (110 against 90) was found to be insignificant by chi-square test. The minor accessory foramen was represented in 144 sides and the major in 33 in double foramina. In triple cases the minor was represented in all but 3 sides.

#### *Direction*

The single foramina were classified according to whether the foraminal opening pointed upwards and forwards (UF), upwards (U), upwards and backwards (UB), or backwards (B).

In the youngest age-group the mental foramen most commonly faced upwards (76.5%), and next upwards-forwards (17.6%). This changed with the second group to upwards (66.7%) and upwards-backwards (27.3%), and this trend continued to adulthood. In the adult male 75.9% faced upwards-backwards and 4.9% backwards. Sporadic cases did not conform to the general trend.

Age differences resulting from this trend between the pooled immature mandibles and the adult female group were found to be significant, by chi-square test, at the level  $P < 0.01$ . Sex differences, by the same test, were insignificant.

#### *Tooth relationship*

An imaginary line was drawn through the centre of each single foramen parallel with the long axis of the nearest tooth.

The tooth or inter-tooth space which this line intersected was recorded.

There was an unmistakable antero-posterior age trend. This is to be expected from the method of successive tooth eruption. Sex differences were insignificant by chi-square test.

Possible association between direction of the mental foramen and its tooth relationship was tested by plotting, using the three commonest tooth relationship positions. As sex differences in both features have been shown to be insignificant the two sexes were pooled. Immature mandibles were excluded.

TABLE 1

*Tooth relationship according to direction of mental foramen in 753 sides of Australian aboriginal adult mandibles*

DIRECTION OF MENTAL FORAMEN	TOOTH RELATIONSHIP OF MENTAL FORAMEN						TOTAL SERIES	
	P2		P2 M1		M1			
		%		%		%		%
UF	3	0.8	3	1.0	3	2.6	9	1.2
U	50	15.2	57	18.4	32	28.1	139	18.5
UB	260	78.8	235	76.1	77	67.5	572	76.0
B	17	5.2	14	4.5	2	1.8	33	4.3
Total	330	100.0	309	100.0	114	100.0	753	100.0

The results (table 1) suggest that a forwardly placed foramen tends to swing towards a backward direction, and vice versa. This association, by chi-square test, is significant at the level  $P < 0.01$ .

An ethnic comparison of tooth relationship (table 2) shows that the Australian mental foramen is appreciably more posteriorly placed relative to the teeth than other reported ethnic groups.

#### THE MENTAL ANGLE

Washburn ('51) states that the alveolar part of the mandible varies with the teeth while the basal part varies with general growth factors. Differential development of these two

parts is reflected in the mental angle. It is thus often quoted as a measure of the degree of alveolar prognathism in the mandible.

The present material showed a range in non-senile mandibles from  $52^{\circ}$  to  $100^{\circ}$ . Even in the widest angles, however, the characteristic features of the chin proper were easily identifiable. There were no "chinless" specimens.

TABLE 2

*Tooth relationship of mental foramen in various ethnic groups*

ETHNIC GROUP	NUMBER OF MANDIBLES	MENTAL FORAMEN BELOW				
		P1	P1P2	P2	P2M1	M1
		%	%	%	%	%
Australian aborigines, male <sup>1</sup>	208	—	0.5	45.4	38.5	15.6
Japanese, male <sup>2</sup>	59	0.9	12.7	66.9	18.6	0.9
Caucasoid, male <sup>3</sup>	100	12.0	22.0	63.0	3.0	—
Hindu, unsexed <sup>4</sup>	75	3.0	38.0	40.0	20.0	—
Unselected, unsexed <sup>5</sup>	100	1.8	23.0	49.4	24.1	1.8

<sup>1</sup> Observed by Murphy, present study.

<sup>2</sup> Observed by Akabori, '34.

<sup>3</sup> Observed by Ashley Montagu, '54.

<sup>4</sup> Observed by Miller, '53.

<sup>5</sup> Observed by Tebo and Telford, '50.

The mean angle in the four immature age groups was successively  $82.3^{\circ}$ ,  $82.1^{\circ}$ ,  $82.5^{\circ}$  and  $81.7^{\circ}$ . The female adult mean was  $80.1^{\circ}$  and the male  $80.7^{\circ}$ . Age differences between the pooled immature mandibles and both adult groups were significant at the level  $P < 0.05$ , using as a test the ratio of the difference to its standard error. By the same test the sex difference was found to be insignificant.

An ethnic comparison (table 3) confirms Cleaver's ('37) finding that the Australian mental angle exceeds that of other reported groups consistently by about  $10^{\circ}$ . The literature, however, lacks comparative figures for modern European, Negro, American aborigine and for other Oceanic groups.

As this divergence of the Australian from other groups parallels that of tooth relationship of the mental foramen

already noted (table 2), it was felt worthwhile to plot them against one another. As sex differences in both features have been shown to be insignificant, the two sexes were pooled. As age differences are significant, immature mandibles were excluded.

TABLE 3

*The mental angle: mean values in various ethnic groups*

ETHNIC GROUP	SEX	NO.	MEAN DEG.	OBSERVER
Australian:	F	215	80.1	Murphy, present study
	M	252	80.7	
Australian:	F	20	81.6	Cleaver 1937
	M	40	78.0	
European:				
Anglo-Saxon, London Museums	F	32	70.6	Morant 1926
	M	32	68.2	
British, Iron Age	F	14	70.3	Goodman and Morant 1939
	M	18	69.8	
Middle Eastern:				
Gizeh, Egypt	F	100	69.8	Martin 1936
	M	172	70.2	
Qau, Egypt	F	43	71.4	Morant 1936
	M	53	71.5	
Asian:				
Tibetan	—	15	61.4	Morant 1923
Hylam Chinese	—	39	72.4	Harrower 1928
Punjabi	M	22	71.2	Cleaver 1937

The results (table 4, fig. 3) show that with a narrow mental angle the proportion of mental foramina below the second premolar and first molar teeth is 43.4% and 12.3% respectively, while with a wide angle the respective proportions are 24.7% and 46.5%. This appears to establish that tooth relationship of the mental foramen varies with the width of the mental angle. This association is highly significant, by chi-square test, at the level  $P < 0.001$ .



Warwick ('50) and Riesenfeld ('56) consider that multiple mental foramina are associated with human types in which the chin is either absent or little developed. If this is true it might be reasonable to expect an association between width of mental angle and the incidence of multiple foramina. Plotting from the present material showed minor differences which, by chi-square test, were insignificant.

TABLE 4

*The mental angle according to tooth relationship of the mental foramen in adult Australian aboriginal mandibles*

MENTAL ANGLE	TOOTH RELATIONSHIP OF MENTAL FORAMEN						TOTAL SERIES	
	P2		P2M1		M1			
		%		%		%		%
Narrow > 77°	139	43.4	86	27.8	14	12.3	239	32.2
Medium 78°-83°	102	31.9	131	42.4	47	41.2	280	37.7
Wide 84° <	79	24.7	92	29.8	53	46.5	224	30.1
Total	320	100.0	309	100.0	114	100.0	743	100.0

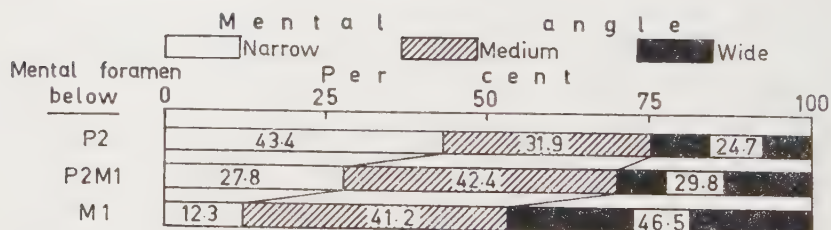


Fig. 3 Percentage bar chart showing association between tooth relationship of mental foramen and width of mental angle. Data from table 4.

#### LINGUAL ASPECT

##### *The alveolar area*

Augier ('31, p. 483) records, highly placed between the central and lateral incisor teeth, "... un miniscule orifice d'un canalicule vasculaire interalvéolaire (foramen mentale alveo-

lare)." Later (p. 508) he cites Bertelli as describing 2nd, 3rd and even 4th pairs of "canalicules interalvéolaires accessoires" between succeeding contiguous tooth sockets. Bertelli, he notes, states that these contain diploic branches of the sublingual artery, and "Ces ramuscules peuvent aussi s'imprimer sur l'os avant d'atteindre leur canalicule osseux."

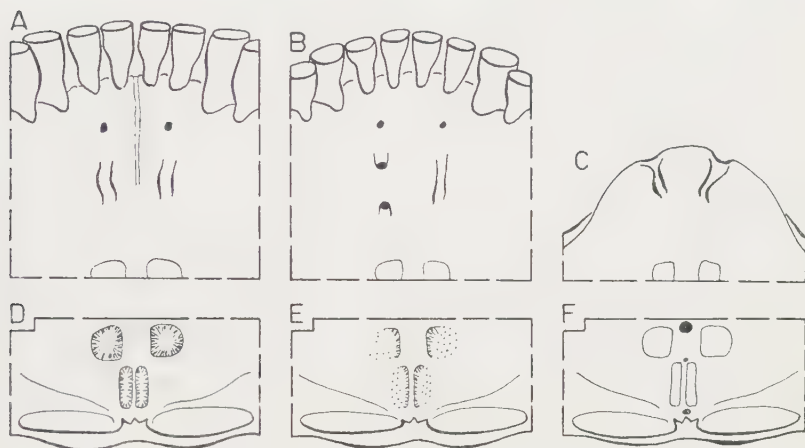


Fig. 4 Lingual aspects of the chin region

Alveolar area

- A Para-sagittal and mid-line grooves
- B Canalization of left para-sagittal groove
- C Para-sagittal grooves in senile mandible

Basal area

- D Typical genial tubercle formation
- E Genial tubercles with adjoining impression
- F The three mid-line nutrient foramina of the genial region

In the present material Augier's "foramen mentale alveolare" was usually readily recognisable on both sides. Two types of grooves were noted traversing the area — mid-line and parasagittal. Both were present together in 56 mandibles (fig. 4A).

*Mid-line groove.* In the four immature age-groups the incidence was successively 66.7%, 81.0%, 66.7% and 53.3%. It was less common in adult males (37.0%) than in adult females

(47.9%). Both age and sex differences were found to be significant, by chi-square test, at the level  $P < 0.05$ .

Diminishing age incidence and paucity in the more fully differentiated adult male suggest that the mid-line groove is associated with bony union at the symphysis menti.

*Para-sagittal grooves.* These have a characteristically coarse punched-out appearance in all groups. They may be unilateral or bilateral, and appear to traverse the area in the direction of the nutrient foramina recorded by Augier. In 3 cases, two male and one female, one of these grooves was converted into a canal (fig. 4B).

The total series incidence was 21.4%. Represented in all groups, age and sex differences were insignificant by chi-square test. The grooves were found to be unilateral on one or other side, or bilateral in about equal thirds.

These grooves appear to be vascular. Their well-marked presence was noted even in a senile mandible with anterior tooth loss (fig. 4C). This suggests that they are associated functionally with the basal rather than the alveolar part of the bone.

### *The basal area*

*Genial tubercles.* Thomson ('16) states, "... in some of the fossil mandibles there is a pit or fossa in place of the raised tubercular area to which the genial muscles are attached in man." He presents examples of various formations in recent man but with no incidence figures. Augier ('31, p. 506) presents Topinard's classification and order of frequency as follows: 1- two superior and two inferior tubercles, 2- two superior and one inferior tubercle, 3- the same disposition but thickened, and 4- a common spine.

In the present material the genial tubercles were usually prominent (fig. 4D). The superior pair were more extensive transversely but less extensive vertically than the inferior. They were set further apart and remained discrete oftener

than the inferior, which tended to coalesce by mid-line calcification. A roughened bony impression, commoner superiorly than inferiorly, often lay adjacent on the lateral side of the tubercle (fig. 4E). In the youngest mandibles this impression was always conspicuous, with the tubercle represented only by a tiny spicule on its medial boundary.

The incidence of Topinard's first class in the four immature age groups was successively 83.3%, 70.0%, 55.6% and 62.2%. The female adult incidence was 45.5% and the male 48.5%. The incidence of his second class was successively 16.7%, 25.0%, 37.0% and 28.9%. The female adult incidence was 48.5% and the male 46.2%. Age differences resulting from this trend between the pooled immature mandibles and the adult female group were significant, by chi-square test, at the level  $P < 0.05$ . Sex differences, by the same test, were insignificant.

The incidence of the adjacent impression in the four immature age groups was successively 100%, 80%, 66.7% and 35.6%. The female adult incidence was 18% and the male 5.4%. These age differences were found to be highly significant, by chi-square test, at the level  $P < 0.001$ . Sex differences by the same test were significant at the level  $P < 0.01$ .

*Genial foramina.* Thomson ('16) names three mid-line nutrient foramina, supragenial above the superior genial tubercles, intergenial between superior and inferior, and infragenial below the inferior.

In the present material these were often readily apparent (fig. 4F). In only 14 mandibles (4.2%) were no such foramina visible to the unaided eye. The supragenial by itself was the commonest (37.1%), and its combination with the infragenial came next (31.7%). Of every 100 foramina, 57.1 were supragenial, 13.8 were intergenial and 29.1 were infragenial. In the total material the supragenial was represented in 87.7%, the intergenial in 21.6%, the infragenial in 45.2% and all three in 7.2%. There were no significant age or sex differences.

## DISCUSSION

*The mental foramen*

Le Double ('06) records two types of accessory foramen. In one case, he states, the double foramen consists of two orifices separated by a tongue of bone, in the other a normally situated foramen has an accessory one in front. He postulates the ossification of a fibrous ligament to account for the first, and the persistence of the canal of the deciduous dentition (canal de Serres) to account for the second. This is supported by Augier ('31, p. 507) who, however, cautiously adds, "La question du canal de Serres ne nous paraît pas définitivement réglée."



Fig. 5 Mechanism at bone-muscle junction  
A — after Thomson ('16) B — after Augier ('31).

Later workers, e.g. Simonton ('23), Ashley Montagu ('54) and Riesenfeld ('56), ignore different types of accessory foramina. It seems likely that this has resulted in varying criteria, which in turn would account for the serious discrepancies pointed out by Riesenfeld in Ashley Montagu's ('54, p. 511) table. On this table the present data would show the Australian sharing with the Negro the highest human incidence (16.7%) of multiple mental foramina.

Riesenfeld ('56) states that most reports agree that multiple foramina are commoner on the right side. In the present study, however, the left side is slightly favored, but not significantly so.

Weidenreich ('36), discussing the multiple mental foramina present in all specimens of *Sinanthropus*, states, "... the impression is given that the main distribution of nerves and blood vessels which takes place in recent man immediately



after emerging from the foramen occurs in *Sinanthropus* within the mandible itself. . . .”

The material of the present study leaves the impression that the minor accessory foramen is formed by ossification of the fibrous septum dividing nerve from blood vessels in the neurovascular bundle, and that the major accessory foramina are due to one or other of the terminal branches of the nerve being given off while the main trunk is still within the bone.

Factors in the direction of the mental foramen are stated to be differential growth of alveolar and basal parts of the mandible (Brash, '24), variation in the distance from the foramen of exit of the nerve to the soft parts it supplies (Warwick, '50), and the gradient of growth being directed posteriorly and superiorly (Ashley Montagu, '54).

Ashley Montagu subdivides the foraminal direction further by introducing “lateral” opening and its combinations with the two dimensions recorded here. As all mental foramina open laterally this is difficult to understand. The impossibility of fitting the material to this conception prevented any valid ethnic comparison.

The present study suggests that the direction of the mental foramen in early life is upwards or upwards-forwards as the area of supply of the mental nerve is largely in that direction. As succeeding teeth erupt the area is extended relatively more in a backward direction as the nerve supplies the skin as far back as the anterior edge of the masseter muscle. Thus a swivelling round takes place with age. In maturity, an anteriorly placed foramen means a greater posterior supply area and a more backward direction, while a posteriorly placed foramen means a greater anterior supply area and a more upward-forward direction.

#### *The mental angle*

This study shows the Australian differing materially from other reported groups in tooth relationship of the mental foramen and in the width of the mental angle. Within the group a high degree of association between these two features

has been established. Both are explicable in terms of the Australian alveolar arch being more forwardly placed on the basal arch of the mandible. Thus it is, in a sense, the teeth which are more forwardly placed relative to the mental foramen rather than the reverse.

Comparison between the human mental angle and that of non-human primates and other mammalian groups as attempted by le Double ('06) is quite invalid as the pogonion, one of the key points for the measurement, is lacking in all but human mandibles.

### *The genial tubercles*

Le Double ('06) cites Walkoff as stating that the genial tubercles disappear with age. Thomson ('16), in explaining the differences in the genial area between non-human primates and man, suggests that a tendon attached to a convex area raises a spine, to a concave area makes a depression (fig. 5A). Augier ('31 p. 83) states that muscle attachment raises the bone at the periphery, thus creating an impression (fig. 5B). He continues (p. 84), "Les apophyses génienne de l'Homme sont essentiellement périmusculaires quand elles sont indépendantes, intermusculaires quand elles sont rapprochées et confondues en une seule spina mentalia. . . ."

The present study suggests a fairly clear-cut sequence of events. In very early life the genial muscles are attached to a bony impression. A tubercle develops on the medial periphery of this impression and expands at its expense till full development. This process may stop before completion even in adult males. A second calcification trend is the bridging of the mid-line barrier, resulting in coalescence of the two inferior tubercles in about half the adult total, and a common spine in a much smaller proportion.

These findings contradict Walkoff and do not support Thomson. They are consistent with Augier except that bone formation is not equally distributed round the periphery but concentrated medially.

The reason for this osteogenesis and its position in man may be associated with proximity to the mid-line osteogenic pressures forming the distinctively human chin.

### *The genial foramina*

Augier ('31) cites Dubreuil-Chambardel's findings in 600 "mandibules diverses" of the supragenial foramen in 75%, the intergenial in 15%, the infragenial in 20%, and all three in 3%.

From the corresponding present figures of 87.7%, 21.6%, 45.2% and 7.2% respectively, it appears that the Australian has a higher incidence of genial foramina but they occur in approximately the same proportions.

### SUMMARY

1. The chin region was examined in 625 Australian aboriginal mandibles, classified into age and sex groups.
2. Details of the following features are recorded.
  - the shape of the labial aspect.
  - the median canal of the chin.
  - the multiplicity, direction and tooth relationship of the mental foramen.
  - the mental angle.
  - the mid-line and parasagittal grooves on the alveolar area of the lingual aspect.
  - the genial tubercles.
  - the genial foramina.
3. The findings are discussed.

### ACKNOWLEDGMENTS

Special thanks are due to Professor A. A. Abbie for continuing encouragement and advice. Other members of this department to whom I am indebted are Miss Gwen Walsh for artistic help, and Mrs. J. Robertson and Miss Meredith Shepherd for help with the material and data. I also wish to thank the Director and the Ethnologist of the South Australian

Museum for access to material in their charge and the provision of working facilities.

## LITERATURE CITED

- AKABORI, K. 1934 Crania Nipponica Recentia. Jap. J. Med. Sci., Sect. 1, Anatomy, 4: 296-303.
- ASHLEY MONTAGU, M. F. 1954 The direction and position of the mental foramen in the great apes and man. Am. J. Phys. Anthrop., 12: 503-518.
- AUGIER, M. 1931 Squelette cephalique, in Poirier and Charpy, Traite d'anatomie Humaine, 4th ed., Tm. 1., Paris.
- BRASH, J. C. 1924 The growth of the jaws and palate. In— The growth of the jaws, normal and abnormal, in health and disease. London.
- CLEAVER, F. H. 1937 A contribution to the biometric study of the human mandible. Biometrika, 29: 80-112.
- GOODMAN, C. N., AND G. M. MORANT 1939 The human remains of the Iron Age and other periods from Maiden Castle, Dorset. Biometrika, 31: 295-312.
- GRAY, H. 1954 Anatomy, descriptive and applied. 31st ed., Ed. by T. B. Johnston and J. Whillis. London.
- HARROWER, G. 1928 A biometric study of one hundred and ten Asiatic mandibles. Biometrika, 20B: 279-293.
- HRDLICKA, A. 1940 Lower jaw. Am. J. Phys. Anthrop., 27: 281-308.
- KEITER, F. 1935 Unterkiefer aus Australien und Neuguinea aus dem Nachlasse Rudolf Pochs. Z. Morph. Anthrop., 33: 190-226.
- LE DOUBLE, A. F. 1906 Traite des variations des os de la face de l'homme. Paris.
- MARTIN, E. S. 1936 A study of an Egyptian series of mandibles, with special reference to mathematical methods of sexing. Biometrika, 23: 149-178.
- MILLER, J. A., JR. 1955 Studies on the location of the lingula, mandibular foramen and mental foramen. Anat. Rec., 115: 349.
- MORANT, G. M. 1923 Appendix to— A first study of the Tibetan skull. Biometrika, 14: 253-260.
- 1926 A first study of the craniology of England and Scotland from Neolithic to Early Historic times, with special reference to the Anglo-Saxon skulls in London museums. Biometrika, 18: 56-98.
- 1936 A biometric study of the human mandible. Biometrika, 28: 84-112.
- RIESENFELD, A. 1956 Multiple infraorbital, ethmoidal and mental foramina in the races of man. Am. J. Phys. Anthrop., 14: 85-100.
- SCHULZ, H. E. 1933 Ein Beitrag zur Rassenmorphologie des Unterkiefers. Z. Morph. Anthrop., 32: 275-366.
- SIMONTON, F. V. 1923 Mental foramen in the anthropoids and man. Am. J. Phys. Anthrop., 6: 413-421.
- TEBO, H. G., AND I. B. TELFORD 1950 An analysis of the variations in the position of the mental foramen. Anat. Rec., 107: 61-66.

- THOMSON, A. 1916 On the presence of genial tubercles on the mandible, of man and their suggested association with the faculty of speech. *J. Anat., Lond.*, 50: 43-74.
- WARWICK, R. 1950 The relation of the direction of the mental foramen to the growth of the human mandible. *J. Anat., Lond.*, 84: 116-120.
- WASHBURN, S. L. 1951 The new physical anthropology. *Trans. New York Acad. Sci.*, 13: 298-304.
- WEIDENREICH, F. 1904 Die Bildung des Kinns und seine angebliche Beziehung zur Sprache. *Anat. Anz.*, 24: 545-555.
- 1936 The mandibles of *Sinanthropus Pekinensis*: a comparative study. *Palaeontologia Sinica*. Peking.





# THE EARLIEST USE OF INDICES FOR SEXING PELTS <sup>1</sup>

LUCILE E. HOYME

*Division of Physical Anthropology  
U. S. National Museum, Washington, D. C.*

ONE FIGURE

One of the most curious anomalies in the history of physical anthropology is the long delay in quantifying the sex differences in the human pelvis. This is surprising for a number of reasons. Sex differences in pelvic morphology were well known to the anthropologists of the late 19th century, and there are frequent metric descriptions of the pelves of different races in the literature of the period. At least one manual on identification had been written (Dwight, 1878) and various bones, including the sternum (Dwight, 1881), had been suggested as sex indicators. Measurements and indices were the usual means of comparing crania and skeletons of different races: Why was not a similar technique applied to the pelvis for determining sex?

The most probable explanation is that the 19th century anthropologists were preoccupied with problems of race. Studies of the skull, the scapula and various other bones all were directed toward establishing the relative rank of the various races. For example, Verneau (1875) devotes only 18 pages to sex differences in the pelvis, but 82 pages to racial comparisons. Although the pelvis seems a most unpromising site for finding race differences, at least in the context of the 20th century concept of race, from the 19th century viewpoint, it was, as Garson (1881) believed, "perhaps next in impor-

<sup>1</sup> Published with the permission of the Secretary of the Smithsonian Institution.

tance to the form of the skull as indicating race characters . . .” (p. 106). Garson was simply echoing the sentiments of Flower (1879) who had written:

As a means of characterizing different human races, the pelvis will probably be found to be, after the cranium, one of the most important parts of the skeleton. The very marked difference of conformation between the pelvis of man and that of the nearest allied animals would certainly lead to the belief that this might be so. (p. 121)

There is much interest in the study of “the pelvic index,” or the ratio of the antero-posterior to the transverse diameter of the brim . . . This is the key to the general form of the organ and gives the most concise numerical estimate of the difference between the pelvis of different individuals and races. As is well known, the ratio is higher in children than adults and is higher in all the anthropoid apes than in man. A high index is therefore an indication of an infantile, or of an animal tendency . . . (p. 122)

This preoccupation with the problems of race seems to have led the anthropologists to minimize sex differences in the pelvis; and the restriction of measurements to features presumably showing little sex differentiation continued the vicious circle. There is, of course, some justification for this, in that they had only a vague idea of the nature of the sex differences to be found in the pelvis. Verneau (1875), to be sure, had compared absolute measurements of European males and females, but apparently he did not examine the distributions of his data, other than making simple comparisons of means. Nevertheless, he did conclude that there were two types of sex difference — those associated with the greater ruggedness of males, and those due to an enlargement of the female pelvic cavity which he attributed to the presence there of the uterus (cf. p. 71).<sup>2</sup> While one may question this reasoning, Verneau was correct in his generalization (p. 69-70) that vertical dimensions are greater in males, but horizontal dimensions are greater in females. It is easy to see why he did not take

<sup>2</sup> He discounts pregnancy as the cause of this enlargement of the female pelvis because it is found in nulliparas (cf. p. 57) and because the pregnant uterus rises above the true pelvis into the abdominal cavity.

the next step, that of calculating indices that would permit him to quantify and compare this sex difference in proportion: He was less interested in sex than in race, and for racial comparisons, the form of the pelvic inlet held more promise.

If racial studies of the pelvis were to be pursued, two obstacles had to be overcome. First of all, there was the problem of sex differences. Verneau's (1875) procedure of pooling the two sexes to obtain adequate racial series was recognized to be unsatisfactory; yet limitation of studies to a single sex was equally undesirable. Perhaps, by selecting the measurements in which the two sexes differed least, comparable figures could be obtained. Which dimensions to use was the second problem. Surveying the list of determinations used by Verneau (1875) and Flower (1879), Garson (1881) complained that most students were using more measurements than were really necessary to describe the form of the pelvis; indeed, instead of clarifying its form, they were obscuring it by a plethora of details. For this reason, he recommended eliminating all but 14 of the 55 measurements taken by Verneau and using, as a standard for comparison, the transverse diameter of the brim. As he pointed out,

The value of indices to facilitate comparisons between measurements is universally recognized. As a rule it has been customary to have several standards of comparison for the various parts of the pelvis; thus a sacral index has been formed by comparing the length and breadth of the bone, an index of height by comparing the height and width of the pelvis, a pelvic index by comparing the antero-posterior diameter of the brim with the transverse diameter of the same and several other indices. In each case a different standard of comparison is taken. This admits only of comparisons being made between corresponding parts, but does not show the relation which the various measurements bear to one another. The breadth of the sacrum can be compared to the length of that bone in different pelves, but it cannot be compared to the transverse diameter of the brim, or to the total breadth of the pelvis, since different standards for compar-

ing those breadths are taken. By adopting a single standard and comparing the several measurements with it, this obvious disadvantage can be removed, and a minute comparison between the various parts is practicable. (p. 108-109)

Garson claimed that a fair approximation of the general shape of any pelvis could be reproduced by plotting the recommended measurements on paper according to a system he had devised. Other measurements, including the "inter-obturator foramina breadth," which Flower had recommended, were excluded: "As they do not appear . . . to indicate specially the general form of the pelvis, they are not included in the list of measurements necessary for that purpose, though they are useful and indeed necessary in formulating minute differences . . ." (p. 127-128). This trend toward standardization of pelvic measurements for racial comparisons reached its culmination with Turner's (1885) use of the pelvic brim index and Sergi's (1899) use of the ilio-pelvic index as means of race classification. Although similar racial comparisons appear in the textbooks from Topinard (1885, p. 1048-1051) to Martin ('28, p. 1120-1133) it is hardly necessary to remind the reader that, for purposes of ranking the human races from ape to European, they are as *passé* as comparisons on the basis of the facial angle. And for the same reason: Anatomically dissimilar structures could be, and were, described by the same number -- a number that meant very little because it attempted to summarize too much.

Apparently the first attempt to use measurements and indices to determine or confirm the sex of pelvises was about 1890. In 1887 the Army Medical Museum in Washington received a large quantity of skeletal material excavated from Ancient Pueblo ruins in the valley of the Gila River in Arizona.<sup>3</sup> This material was turned over to Dr. Washington Matthews for study, one of the steps, of course, being the determination of the sex of the skeletons. In preparing their report (1891) on

<sup>3</sup> Transferred to the U. S. National Museum in 1904, where it bears catalogue numbers 239,201-718.



these skeletal remains, Drs. Washington Matthews and John S. Billings include the following discussion of the pelvis:

No measurement has been permitted to originate with us. The series of 19 measurements are compiled from Garson and Verneau. Fritsch, Davis and Bacarisse have also been consulted and the choice of each measurement determined by its frequency in use and its clear definition fully as much as by its apparent morphological utility . . .

The indices which have been calculated by different authors are very varied. In view of this fact, and also because all published series of measurements which we have examined deal with series which compared to craniological series are absurdly small, we have limited our indices to the two which Topinard especially recommends, *and a few others which appear most useful in the discrimination of sex.*<sup>4</sup>

Verneau, however seems to base his discussions of sex on anatomical difference and absolute measurements, while J. G. Garson and most other writers have given us practically no information concerning the male pelvis. Hence, as we are dealing with an unknown people, indeed almost all American tribes are unknown to pelvimetricians, and a people of probably conspicuously small stature, we might very readily go astray in applying to any great extent the canons or results of European anthropometry.

With these considerations in view we have decided upon the following indices:

First. — The breadth-height index or relation of the maximum external width of the pelvis at the iliac crest to its maximum height, or, which is the same thing, the maximum length of the innominate bone.

$$\text{Formula: } \frac{\text{Pelvic width} \times 100}{\text{Pelvic height}}$$

Second.—Index of the superior strait.

$$\text{Formula: } \frac{\text{Antero-posterior diameter of brim} \times 100}{\text{Transverse diameter of brim}}$$

Third.—Index of the pubo-ischiatic depth.

$$\text{Formula: } \frac{\text{Pubo-ischiatic depth} \times 100}{\text{Maximum width of superior strait}}$$

<sup>4</sup> Italics mine.

Fourth.—Index of sacral length.

$$\text{Formula: } \frac{\text{Sacral length} \times 100}{\text{Maximum width of superior strait}}$$

Upon inspecting the pelves we find them forming two groups. In the one group are Nos. H.6, H.7, H.14, H.18, H.19, H.25, H.41 and H.72. These present all the ordinary characteristics of the male pelvis. In the other group we find Nos. H.1, H.5, H.8, H.10, H.15, H.36, H.39, H.45, H.57 and H.59. These represent females.

\* \* \*

The data furnished by the breadth-height index and the index of the superior strait accord to the Saladoans a high place in the human series. With regard to the breadth-height index, both the males and the females stand at the top of the scale. With regard to the index of the superior strait, the females stand at the highest . . . end of the scale, above the Europeans. The males occupy a medium position.

*The other indices are of use in comparing the sexes, but we have never seen any comparative data concerning them in print.*<sup>5</sup>

We have prepared four ordinations, one for each index. *These, especially the indices of pubo-ischiatic depth and that of sacral length, show very prettily the natural grouping of the sexes.*<sup>5</sup> (See Tables LXII to LXV, inclusive) (pp. 220-221).

Inspecting the tables given (fig. 1), one must agree with the authors that their pubo-ischiatic and sacral length indices do indeed "show very prettily the natural grouping of the sexes." So prettily, in fact, that one wonders whether the authors did not re-examine the two individuals which seem to deviate from the rule. Yet, since sexing was done on the basis of the entire skeleton, including the skull (p. 170), they must have felt reasonably sure of their determinations. Re-examining H.7 (USNM 239,229), one finds that the pelvis is a puzzler. The symphyseal portion of the pubic bone is close to the typical male form, but the very short sacrum and wide sciatic notch appear more feminine. The left ilium was damaged when it was collected, and the right innominate has been

<sup>5</sup> Italics mine.

TABLE LXII.—*Ordination of breadth-height indices of 14 pelves—Salado.*

	Designation of skeleton.	Index.	Sex.		Designation of skeleton.	Index.	Sex.
1	H. 41	131.18	Male.	8	H. 7	145.83	Male.
2	H. 14	131.77	Male.	9	H. 72	146.96	Male.
3	H. 5	135.32	Female.	10	H. 10	148.92	Female.
4	H. 6	136.36	Male.	11	H. 36	149.42	Female.
5	H. 59	137.07	Female.	12	H. 15	152.09	Female.
6	H. 25	140.60	Male.	13	H. 39	152.38	Female.
7	H. 8	142.32	Female.	14	H. 57	152.66	Female.

TABLE LXIII.—*Ordination of superior strait indices of 18 pelves—Salado.*

	Designa- tion of skel- eton.	Index.	Sex.		Designa- tion of skel- eton.	Index.	Sex.
1	H. 39	69.04	Female.	10	H. 45	82.26	Female.
2	H. 59	69.06	Female.	11	H. 57	82.53	Female.
3	H. 7	74.04	Male.	12	H. 25	82.81	Male.
4	H. 15	74.61	Female.	13	H. 5	84.72	Female.
5	H. 36	76.92	Female.	14	H. 8	85.82	Female.
6	H. 1	77.95	Female.	15	H. 18	86.03	Male.
7	H. 41	78.63	Male.	16	H. 19	89.65	Male.
8	H. 72	80.14	Male.	17	H. 6	91.45	Male.
9	H. 10	80.41	Female.	18	H. 14	103.44	Male.

TABLE LXIV.—*Ordination of 18 pubo-ischiatic indices—Salado.*

	Designa- tion of skel- eton.	Index.	Sex.		Designa- tion of skel- eton.	Index.	Sex.
1	H. 15	59.23	Female.	10	H. 18	68.99	Male.
2	H. 59	62.58	Female.	11	H. 72	69.85	Male.
3	H. 45	63.12	Female.	12	H. 36	70.76	Female.
4	H. 57	64.28	Female.	13	H. 7	71.75	Male.
5	H. 1	65.35	Female.	14	H. 6	76.06	Male.
6	H. 8	66.14	Female.	15	H. 14	77.58	Male.
7	H. 10	66.43	Female.	16	H. 41	80.34	Male.
8	H. 5	66.66	Female.	17	H. 25	81.25	Male.
9	H. 39	66.66	Female.	18	H. 19	81.89	Male.

TABLE LXV.—*Ordination of 15 sacral length indices—Salado.*

	Designa- tion of skel- eton.	Index.	Sex.		Designa- tion of skel- eton.	Index.	Sex.
1	H. 10	65.03	Female.	9	H. 5	77.08	Female.
2	H. 59	66.18	Female.	10	H. 8	80.31	Female.
3	H. 7	67.93	Male.	11	H. 72	82.35	Male.
4	H. 1	72.44	Female.	12	H. 14	83.62	Male.
5	H. 45	73.75	Female.	13	H. 41	86.32	Male.
6	H. 15	73.84	Female.	14	H. 6	94.87	Male.
7	H. 36	76.92	Female.	15	H. 19	95.68	Male.
8	H. 57	76.98	Female.				

Fig. 1 Tables LXII, LXIII (p. 262), LXIV, LXV (p. 263) from Matthews and Billings, 1891.

lost, so that most of their measurements cannot be checked, and the number of observations possible is limited. Nevertheless, it is probably male. H.36 (USNM 239,231) is undoubtedly a female. Possibly the high pubo-ischiatic index is due to the considerable development in this individual of the pectineal crest.<sup>6</sup>

Recalling Verneau's rule-of-thumb regarding pelvic proportions, it is easy to see why Matthews and Billings obtained the results they did. The index of the superior strait is seen to be ineffective for separating the sexes, since both of the dimensions are horizontal ones and both reflect a similar degree of enlargement of the pelvic inlet. The breadth-height index might be expected to show some sex differences, as indeed the average does, but there is no clear-cut distinction in the ranges. The pubo-ischiatic and sacral length indices, on the other hand, are excellent sex indicators, since both compare the depth of the true pelvis (a vertical dimension) to its width (a horizontal dimension).

These very useful tools for discriminating between the sexes should have started a chain of studies, investigating, first, the possibility that analogous sex differences occurred in other races and, having demonstrated such differences, determining their nature. Once this was done measurements could be refined and more effective discriminating indices derived. Yet nothing of the sort happened for more than fifty years. The question of sex differences in the pelvis remained open, so that as late as '36 Howells and Hotelling could address themselves to the old controversy as to whether sex differences in the pelves of "primitive" people were greater or less than those distinguishing the sexes in Europeans.

Not until '42 did Washburn point out that there was a considerable metric difference in the pelves of the two sexes in a number of the non-human primates and that this difference could be localized. By focussing attention on the growth

<sup>6</sup> The authors define pubo-ischiatic depth as "The distance between the upper surface of the pubis and the lower surface of the ischium, from the smooth level surface on the pubic side of the ilio-pectineal suture above to the lowest part of the tuber ischii." (p. 221)

of the pubic bone he provided an explanation for Verneau's old generalization about pelvic proportions in the two sexes, and the impetus for a new series of studies of sex differences in the pelvis. Naturally, the first step was to obtain data establishing this difference in the pelves of various human groups and these were supplied (Washburn, '48, '49; Hanna and Washburn, '53). These studies, calling attention to the problem and suggesting possible approaches have led, and will continue to lead, to new investigations on the pelvis. They can take any of three directions — that of describing these differences in new racial groups, that of developing better measurements and/or better ways of handling the measurements currently being used, and that of providing an explanation of the differences in terms of growth patterns. All three of these courses are necessary. It remains to be seen which course anthropologists will now take and which course will turn out to be the most fruitful.

## LITERATURE CITED

- DWIGHT, T. 1878 The identification of the human skeleton. Boston, 54 pp.  
 ——— 1881 The sternum as an index of sex and age. *J. Anat. and Physiol.*, 15: 327-330.
- FLOWER, W. H. 1879 On the osteology and affinities of the natives of the Andaman Islands. *J. Anthr. Inst. Gr. Brit. and Ireland*, 9: 108-135.
- GARSON, J. G. 1881 Pelvimetry. *J. Anat. and Phys.*, 16: 106-134.
- HANNA, R. E., AND S. L. WASHBURN 1953 The differentiation of the sex of skeletons, as illustrated by a study of the Eskimo pelvis. *Human Biol.*, 25 (1): 21-27.
- HOWELLS, W. W., AND H. HOTELLING 1936 Measurements and correlations of Indians of the Southwest. *Am. J. Phys. Anthropol.*, 21: 91-106.
- MARTIN, R. 1928 *Lehrbuch der Anthropologie*. 2nd ed., Jena, 3 v., 1816 pp.
- MATTHEWS, W., AND J. S. BILLINGS 1891 The human bones of the Hemenway Collection in the United States Army Medical Museum at Washington. 7th Memoir, v. 6, *Nat. Acad. Sci.*, p. 139-286 + 59 pl.
- SERGI, G. 1899 L'indice ilio-pelvico o indice sessuale nel bacino delle razze umane. *La Clinica Ostetrica*, 1: 102-108.
- TOPINARD, P. 1885 *Eléments d'anthropologie générale*. Paris, xv + 1157 pp.
- TURNER, W. 1885 The index of the pelvic brim as a basis of classification. *J. Anat. and Physiol.*, 20: 125-143.
- VERNEAU, R. 1875 *Le bassin dans les sexes et dans les races*. Paris, 156 pp., 3 tables, 16 pl.



- WASHBURN, S. L. 1942 Skeletal proportions of adult langurs and macaques. *Human Biol.*, 14: 444-472.
- 1948 Sex differences in the pubic bone. *Am. J. Phys. Anthrop.*, n.s. 6: 199-207.
- 1949 Sex differences in the pubic bone of the Bantu and Bushman. *Am. J. Phys. Anthr.* n.s. 7: 425-432.

A BLOOD GROUP GENETICAL SURVEY  
IN AUSTRALIAN ABORIGINES AT  
HAAST'S BLUFF, CENTRAL  
AUSTRALIA <sup>1</sup>

R. T. SIMMONS,<sup>2</sup> N. M. SEMPLE,<sup>3</sup> J. B. CLELAND <sup>4</sup>

AND J. R. CASLEY-SMITH

*Commonwealth Serum Laboratories, Melbourne, Australia, and  
the University of Adelaide, Adelaide, Australia*

Investigations concerning the blood groups of Australian aborigines have been made for over 35 years, with the result that the A-B-O blood groups for natives in most parts of Australia are known. One of us (J.B.C.) demonstrated that unmixed aborigines of South Australia and the Northern Territory did not possess group B, and that the frequency of O was generally greater than the frequency of A. Dr. A. H. Tebbutt of Sydney in still earlier surveys had found group B in natives of Barambah, Queensland.

It is now known that group B had been introduced to Australian aborigines by admixture with other peoples, particularly by Melanesians of New Guinea, in the Cape York area, by Malays on the west coast of the Gulf of Carpentaria, by Chinese gold seekers in Queensland during and after the gold-rush, and also by New Hebrideans (Melanesians) brought to Queensland many years ago to work in the sugar cane fields.

<sup>1</sup> The blood samples studied in this survey were collected in 1956 by the University of Adelaide Anthropological Expedition to Haast's Bluff. The expedition was financed largely by the Wenner-Gren Foundation for Anthropological Research, Inc., and by the University of Adelaide.

<sup>2</sup> Research Associate, University of California, Los Angeles; Consultant, Commonwealth Serum Laboratories, Melbourne.

<sup>3</sup> Biochemist, Commonwealth Serum Laboratories.

<sup>4</sup> Emeritus Professor of Pathology, University of Adelaide.

All the early A-B-O blood group surveys in Australian aborigines have been tabulated, and the distribution of group B discussed by Birdsell and Boyd ('40), and by Wilson, Graydon, Simmons and Bryce ('44).

Birdsell and Boyd reported the M-N types for 730 Australian aborigines, while Wilson et al. presented M-N results for 649 natives living in different parts of Australia. The aborigines were found to possess the highest frequency of gene  $n$  known in the world at that time. Higher frequencies of  $n$  have since been found in the peoples of New Guinea and Papua.

The next surveys made were mainly concerned with the distribution of the Rh types, and again it was found that the Rh genes present and their frequencies, exhibited a unique pattern. Genes  $R^1$ ,  $R^2$ ,  $R^0$ ,  $R^z$  and possibly  $r'$  were found, the high frequency of  $R^z$  being exceptional. On no occasion has the Rh negative gene  $r$  been found in Australian aborigines, and several thousand natives have now been tested. Tests for other blood group systems have been made on various aboriginal groups during the past 10 years. The results of a most extensive survey on nearly 2000 natives in Western Australia conducted by Professor J.B. Birdsell in association with one of us (R.T.S.) have not yet been fully analysed for publication. The recent papers relative to blood grouping in Australian aborigines have been listed by Simmons, Graydon and Semple ('54) who also presented blood grouping data for aborigines living at Yuendumu, Darwin and Elsey Station (Northern Territory) and Ernabella (South Australia).

The purpose of the present investigation was to determine whether aborigines living at Haast's Bluff which is approximately 150 miles west of Alice Springs in Central Australia, exhibit gene frequencies comparable with those of other natives in Central Australia, and whether the Diego ( $Di^a$ ) blood group antigen is present in Australian aborigines in this area.

In the present survey 7 tribes were represented as follows: Aranda, Kukatja, Ngalia, Pintubi, Loritja, Pitjandjara and Panika.

#### MATERIALS AND METHODS

The field work was carried out by members of the University of Adelaide Expedition, and the blood samples were sent to Melbourne by air-freight packed in ice in "Stanley" jars. The technical methods employed in the investigation were those described by Simmons, Graydon, Semple and Taylor ('51).

#### RESULTS AND DISCUSSION

The A-B-O groups, the M-N and Rh types and the respective gene frequencies are presented in table 1, while other observations are given in table 2.

*A-B-O groups.* No example of group B or sub-group  $A_2$  was found. The gene frequencies are  $A$  .333 and  $O$  .667. These frequencies are almost the same as those found for 93 natives at Yuendumu,  $A$  .312 and  $O$  .688. The general picture for Australia is in the order of  $A$  .25 and  $O$  .75 which is similar.

*The M-N types.* The gene frequencies at Haast's Bluff are  $m$  .236 and  $n$  .764, while at Yuendumu the frequencies are  $m$  .280 and  $n$  .720. Birdsell and Boyd ('40) found  $m$  .178 and  $n$  .822 for 730 aborigines, while Wilson, Graydon, Simmons and Bryce ('44) found  $m$  .297 and  $n$  .703 in surveys in all Australian States.

No tests were made to determine the M-N-S subdivisions because the S antigen is accepted as being absent in aborigines, and because of shortage of anti-S testing reagent.

*The Rh types.* The calculated gene frequencies are  $R^1$  .560,  $R^2$  .252,  $R^0$  .119 and  $R^z$  .069. In the series there were three examples of  $Rh_0Rh_0$  (2.9%), and 7 examples of  $Rh_1Rh_z$  (6.7%). The Rh frequencies previously found for Northern Territory natives were  $R^1$  .541,  $R^2$  .371,  $R^0$  .072 and  $R^z$  .016. In an earlier survey by Simmons and Graydon ('48) for 234 aborigines of which about one half were in Queensland, the

frequencies were  $R^1$  .564,  $R^2$  .201,  $R^0$  .085,  $r'$  .129,  $R^z$  .021. The general Rh pattern for aborigines at Haast's Bluff and in other States is similar. It was pointed out by Simmons et al. ('54) that tests in Western Australia aborigines indicate that both  $Rh_0(D^u)$  variants and  $rh'$  exist in these natives. As the  $Rh_0(D^u)$  variants were greatly in excess, the frequency given for  $rh'$  as .129 must largely represent  $Rh_0$  variants of "low-grade." No  $Rh_0$  variants were found in the present series.

*The blood group P.* In tests for the blood group P, 23% of the samples were found to be P positive. In a previous survey in this region 65% were recorded as P positive, but the samples were collected over a wide area.

*The Lewis ( $Le^a$ ) blood group.* No example of the Lewis ( $Le^a$ ) antigen was found in the present series, although the antigen has been shown to be present in about 7.3% of natives in the Northern Territory.

*P.T.C. taste tests.* In the P.T.C. taste tests 50% were recorded as tasters, but there were 32 natives for whom no decision could be reached as to their reaction. Previous tests in the Territory have indicated that about 50% are tasters, although the interpretation of taste reactions in these people has proved most difficult.

*The Diego ( $Di^a$ ) blood group.* No previous blood genetic surveys have been done on the Haast's Bluff natives so that the data presented here are new. Most important possibly are the results of tests for the Diego ( $Di^a$ ) antigen which indicate that no evidence of this antigen was found in 112 blood samples tested. The Diego blood group was first reported by Levine, Koch, McGee and Hill ('54), and was thought to be a "private" blood group. It has since been shown to occur in from 2% to over 50% in the blood of South American Indian groups, peoples of mixed blood in Venezuela, Brazilian Indians, North American Indians, (Chippewa and Crees), and in Chinese and Japanese resident in Canada and Venezuela. The  $Di^a$  antigen was not detected in the blood of 156 Eskimos from the Eastern Canadian



Arctic, which includes Hudson Bay, Baffinland and Labrador. The literature relative to above investigations was cited by Simmons ('57), who reported the apparent absence of this antigen in preliminary tests in the Australasian area, and in Polynesians of Eastern and Central Polynesia.

TABLE 1

*A-B-O, M-N and Rh blood groups and gene frequencies in Australian Aborigines at Haast's Bluff, Central Australia*

NO. TESTED	BLOOD GROUPS			GENE FREQUENCIES						
	O	A <sub>1</sub>		A	O					
126	56	70								
	44.4%	55.6%		.333	.667					
	M	MN	N	m	n					
	5	49	71	.236	.764					
	4.0%	39.2%	56.8%							
105	Rh <sub>1</sub> Rh <sub>1</sub>	Rh <sub>1</sub> Rh <sub>0</sub>	Rh <sub>2</sub>	Rh <sub>1</sub> Rh <sub>2</sub>	Rh <sub>0</sub> Rh <sub>0</sub>	Rh <sub>1</sub> Rh <sub>2</sub>	R <sup>1</sup>	R <sup>2</sup>	R <sup>0</sup>	R <sup>2</sup>
	32	12	9	42	3	7	.560	.252	.119	.069
	30.5%	11.4%	8.6%	40.0%	2.9%	6.7%				

TABLE 2

*Summary of other tests performed on Australian Aborigines at Haast's Bluff*

Rh VARIANTS	P+	Le (a+) (LEWIS)	Di (a+) (DIEGO)	TASTE REACTIONS	
				TASTER	NON-TASTER
0/105	23/100	0/100	0/112	37	37
0%	23%	0%	0%	50%	50%

If the Diego antigen is a Mongoloid marker as earlier work suggested, it is surprising that it was not detected in either Eskimo or in Polynesian blood samples. Failure to detect it, however, does not prove the absence of a Mongoloid component in these people, because in some South American peoples it was found in only 2% of those tested. Much more work will be necessary before the true picture of the racial distribution of the Di<sup>a</sup> antigen becomes evident.

A small series of tests was made for atypical blood group antibodies in the Haast's Bluff natives. The sera of 13

mothers who had had multiple births were tested by saline and albumin agglutination tests, and by the antiglobulin technique using as test cells those of the husband where A-B-O compatible, and/or those of other male members of the community. No atypical antibodies were detected in these tests.

#### ACKNOWLEDGMENTS

We are grateful to Dr. J. J. Graydon of the Commonwealth Serum Laboratories who calculated the gene frequencies presented in the tables. The anti-Diego serum used in the investigation was generously supplied by Dr. M. Layrisse of Caracas, Venezuela, who also sent Di(a+) blood as a control. We are also indebted to Professor A.A. Abbie of the University of Adelaide, who led the expedition, for making the material available for this investigation.

#### SUMMARY

Blood samples from Australian aborigines at Haast's Bluff, Central Australia, have been tested for the blood groups ABO, MN, Rh, P, Le<sup>a</sup> and Di<sup>a</sup>. P.T.C. taste tests were also carried out. The blood group frequencies conform generally to those expected for the Central Australian area. The absence of the blood group antigen Di<sup>a</sup> in the Australasian area is briefly mentioned in relation to its presence in American Indians, and its absence in Eskimos and Polynesians. No atypical blood group antibodies were found in the sera of a few mothers who had had multiple births.

#### LITERATURE CITED

- BIRDELL, J. B., AND W. C. BOYD 1940 Blood groups in the Australian aborigines. *Am. J. Phys. Anthropol.*, XXVII: 69-90.
- LEVINE, P., E. A. KOCH, R. T. MCGEE AND G. H. HILL 1954 Rare human isoagglutinins and their identification. *Am. J. Clin. Path.*, 24: 292-304.
- LEWIS, M., B. CHOWN AND H. KAITA 1956 Further observations on the blood factor Di<sup>a</sup>. *Nature*, 178: 1125.
- SIMMONS, R. T. 1957 The Diego (Di<sup>a</sup>) blood group: Tests in some Pacific peoples. *Nature*, 179: 970-971.
- SIMMONS, R. T., AND J. J. GRAYDON 1948 The Rh blood types in Australian aborigines. *Med. J. Australia*, 2: 113-119.

- SIMMONS, R. T., AND J. J. GRAYDON 1957 A blood group genetical survey in eastern and central Polynesians. *Am. J. Phys. Anthropol.*, 15: 357-366.
- SIMMONS, R. T., J. J. GRAYDON AND N. M. SEMPLE 1954 A blood group genetical survey in Australian aborigines. *Am. J. Phys. Anthropol.*, 12: 599-606.
- SIMMONS, R. T., J. J. GRAYDON, N. M. SEMPLE AND C. N. D. TAYLOR 1951 Blood, taste and secretion: A genetical survey in Maoris. *Med. J. Australia*, 1: 425-431.
- WILSON, H., J. J. GRAYDON, R. T. SIMMONS AND L. M. BRYCE 1944 The blood groups of Australian aborigines. *Med. J. Australia*, 2: 581-589.



# THE BLOOD GROUPS OF SOUTH AMERICAN INDIANS

FRANCISCO M. SALZANO<sup>1</sup>

*Instituto de Ciências Naturais, Universidade do Rio Grande do Sul,  
Pôrto Alegre, Brazil; and Department of Human Genetics,  
University of Michigan, Ann Arbor*

## INTRODUCTION

Since the discovery of the Hirzfelds, that the frequencies of the blood groups vary from one population to another, an enormous amount of information has been gathered all over the world concerning these characteristics. Boyd's ('39) and Mourant's ('54) compilations attempted to bring together and evaluate these data. The South American Indians have been fairly well studied during this period. But since Mourant did not tabulate the published data on the ABO system, and eighteen years passed since Boyd's work, no comprehensive account of the data thus far obtained is available.<sup>2</sup>

Moreover, in the cited reviews and in the original papers in general, no tests of homogeneity were performed for the comparison of the several samples studied. It was also a constant feature of all these studies that the treatment was of the South American Indians as a whole, the comparisons being made between them and people from other parts of the world. If this was a necessity in the beginning, due to the small amount of data available, it can be said now that this is no longer the case, inasmuch as there exist no less than 95 papers dealing with the blood groups of South American Indians.

<sup>1</sup> Fellow of the Rockefeller Foundation, 1956-1957.

<sup>2</sup> Boyd has made in 1950 a short review of the blood groups of the South American Indians, with no attempt, however, to cover all the literature published. This is particularly true in relation to the Brazilian Indians, represented by only one sample in his review.



The present paper attempts to bring together all the data concerning the blood groups of South American Indians, to analyze it statistically, and to interpret it in terms of the techniques used and the physical and biological differences which exist among the Indian tribes of this continent. In particular, an attempt will be made to examine Imbelloni's ('38 — see also Biasutti, '57) classification of the South American Indians, drawn up without regard to the blood groups findings, in the light of the latter.

Imbelloni (i.e.) recognizes 6 Indian racial groups in South America (see fig. 1): the *Andidos*, short, with rounded small-vaulted heads, and inhabiting the Andes highlands; the *Amazonidos*, of short to medium stature, with brachycephalic tendencies and inhabiting the Amazon basin and other parts of the Brazilian territory; the *Pampidos*, very tall and with a mostly long head form, living in the Pampa regions of Chile, Argentina, Uruguay, and Brazil (Mato Grosso); the *Fueguidos*, a relict group of short, dolichocephalic people, now restricted to a few survivors in southern Chile and the Brazilian coast; and the *Istmidos* and *Laguidos*, not shown in figure 1 or discussed in the paper, since they are not numerous at present, and no data is available about their blood groups.

#### THE DATA

##### *The ABO blood groups*

Data concerning this system is available for 58 Indian populations in South America, and are presented in table 1 and figure 1. Table 1 shows phenotype and gene frequency estimates, as well as  $\chi^2$  and P values for each sample, in regard to the fit of the observed phenotype frequencies with the corresponding gene frequency estimates. The latter are corrected estimates obtained by Bernstein's ('30) method. The test of goodness of fit between the observed and expected phenotype frequencies was performed according to the formula given by Taylor and Prior ('38).



Fig. 1 Map of South America, showing the places from which ABO blood group determinations are available. The geographical distribution of several of Imbelloni's racial groups is also shown; they are separated by unbroken lines. The broken lines separate different countries. The circles represent samples with almost exclusively O genes ( $p$  and  $q$  less than .005). The squares, samples with high frequencies of O genes and fair amounts of A and B ( $p$  and  $q$  > .005). The triangles, samples with high frequencies of O genes, fair amounts of A ( $p$  > .005), and almost none B ( $q$  < .005). The inverted triangles, samples with high frequencies of O, fair amounts of B ( $q$  > .005), and almost none A ( $p$  < .005).

TABLE 1

*ABO blood group phenotype and gene frequency estimates in Indian populations from several South American countries.  $\chi^2$  and P values for the fit between the observed phenotypes and those expected for the gene frequencies given are shown in the two last right hand columns*

SOURCE	TRIBE	LOCALITY	NO. STUD.	O	A	B	AB	p	q	r	$\chi^2$	P
<i>Venezuela:</i>												
Layrisse et al., '55 <sup>1</sup>	Caribs	Cachama, S. Clara	169	100.00	—	—	—	—	—	1.00000	—	—
Layrisse and Arends, '57a	Guajiros	Ziruma	152	94.74	3.95	1.31	—	.01994	.00657	.97349	0.047	> 0.80
Layrisse, unpublished	Piaroas	Terr. Amazonas	24	100.00	—	—	—	—	—	1.00000	—	—
Layrisse, unpublished	Guahibos	Terr. Amazonas	76	100.00	—	—	—	—	—	1.00000	—	—
<i>Surinam:</i>												
Kahn, '36	Alkuyana	Gran Borec, Green Casava falls	70	100.00	—	—	—	—	—	1.00000	—	—
Collier et al. '52	Carib	Near Paramaribo	177	95.48	2.26	2.26	—	.01136	.01136	.97728	0.037	> 0.80
Collier et al. '52	Arawak	Near Paramaribo	88	98.86	—	1.14	—	—	.00572	.99428	—	—
<i>Colombia:</i>												
Reichel-Dolmatoff and Reichel-Dolmatoff, '44	Pijao	Mun. de Natagaima	281	100.00	—	—	—	—	—	1.00000	—	—
Reichel-Dolmatoff and Reichel-Dolmatoff, '44	Pijao	Mun. de Coyaima	439	96.35	3.42	—	0.23	.01841	.00115	.98044	1.303	> 0.20
Reichel-Dolmatoff and Reichel-Dolmatoff, '44	Pijao	Mun. de Ortega	331	86.40	7.86	3.02	2.72	.05403	.02893	.91704	67.450	< 0.001
Lehmann et al., '46 <sup>1</sup>	Kwaker	Frontier with Ecuador	172	96.52	1.74	1.74	—	.00874	.00874	.98252	0.018	> 0.80
Duque Gomez, '44	Carib	Dep. de Caldas	540	96.11	3.15	0.74	—	.01588	.00371	.98041	0.054	> 0.80
Lehmann et al., '43	Guambiano-											
	Kokonuko	Mun. de Silvia	210	95.71	2.86	1.43	—	.01440	.00718	.97842	0.043	> 0.80
Arcila Velez, '43	Paez	Dep. de Cauca	246	92.68	4.07	3.25	—	.02056	.01638	.96305	0.179	> 0.50
Arcila Velez, '46	Caranauta	Dep. de Antioquia	142	92.25	6.34	1.41	—	.03222	.00708	.96070	0.060	> 0.80
Paez Perez and Freudenthal, '44	Quillacinga	Pasto (Dep. de Narino)	103	88.35	6.80	4.85	—	.03462	.02456	.94082	0.186	> 0.50
Paez Perez and Freudenthal, '44	Sibundoy and Santiaguinos	Upper Putumayo	251	86.45	6.38	7.17	—	.03245	.03654	.93101	0.644	> 0.30
<i>Ecuador:</i>												
Santiana, '52	Caras	Andes	1838	95.43	3.21	0.87	0.49	.01865	.00681	.97454	207.030	< 0.001
Santiana, '52	Panzalcos	Andes	2570	94.43	3.97	1.52	0.08	.02046	.00803	.97151	2.197	> 0.10
Santiana, '52	Purunas	Andes	1410	94.61	4.47	0.78	2.14	.03331	.00461	.97208	10.423	< 0.01

	Quijos	Amazonas	944	97.99	1.80	0.21	—	±.00109 ±.00060 ±.00127		
Santiana, '52	Jivaros	Amazonas	111	100.00	—	—	—	.00904 .00105	.98991	—
Santiana, '52	Amazonidos		1055	98.20	—	—	—	—	1.00000	—
Santiana, '52					1.61	0.19	—	.00809 .00094	.99097	—
Santiana, '52	Colorados	Sector occidental	97	100.00	—	—	—	±.00195 ±.00067	±.00206	—
Santiana, '52	Cayapas	Sector occidental	62	100.00	—	—	—	—	1.00000	—
					—	—	—	—	1.00000	—
<i>Peru:</i>										
Aree Larreta, '30	Several tribes	Mocha and Laredo	200	100.00	—	—	—	—	1.00000	—
Marroquin, '46	Quechuas and Ainaras									
Weiss, '48	Several	Dep. de Puno	500	96.00	3.00	1.00	—	.01511 .00501	.97988	0.052 > 0.80
Sau Martin, '51	Not specified	Lamas	119	92.44	1.68	5.88	—	.00844 .02985	.96146	0.062 > 0.80
		Dep. de Junin	200	86.50	9.50	4.00	—	.04872 .02021	.93107	0.430 > 0.50
<i>Brazil:</i>										
Biocca and Ottensooser, '44	Tucano	Upper Rio Negro, Amazonas	180	100.00	—	—	—	—	1.00000	—
Biocca and Ottensooser, '44	Tariana	Amazonas	48	100.00	—	—	—	—	1.00000	—
Biocca and Ottensooser, '44	Macu	Amazonas	9	100.00	—	—	—	—	1.00000	—
Lima, '50 <sup>3</sup>	Camayura	Mato Grosso	60	100.00	—	—	—	—	1.00000	—
Lima, '50	Waura	Mato Grosso	80	100.00	—	—	—	—	1.00000	—
Lima, '50	Kalapalo	Mato Grosso	81	100.00	—	—	—	—	1.00000	—
Lima, '50	Mehinaku	Mato Grosso	47	100.00	—	—	—	—	1.00000	—
Lima, '50	Bacairi	Mato Grosso	108	100.00	—	—	—	—	1.00000	—
Pantin and Junqueira, '52 <sup>3</sup>	Camayura	Mato Grosso	32	100.00	—	—	—	—	1.00000	—
Pantin and Junqueira, '52	Kalapalo	Mato Grosso	24	100.00	—	—	—	—	1.00000	—
Pantin and Junqueira, '52	Several	Mato Grosso	17	100.00	—	—	—	—	1.00000	—
Junqueira and Wishart, '56 <sup>4</sup>										
Da Silva, '49	Caraja	Mato Grosso	66	100.00	—	—	—	—	1.00000	—
Offensooser and Pasqualin, '49	Several	Mato Grosso	587	100.00	—	—	—	—	1.00000	—
Offensooser and Pasqualin, '49	Caiua	Mato Grosso	237	100.00	—	—	—	—	1.00000	—
Martins and Bastos, '35	Bororo	Mato Grosso	119	100.00	—	—	—	—	1.00000	—
	Botocudo	Rio Doce, Minas Gerais and Espirito Santo								
Ribeiro et al., '35 <sup>2</sup>	Guarani	Missoes, R. G. do Sul	35	100.00	—	—	—	—	1.00000	—
Fernandes, '39 <sup>2</sup>	Caingang	Palmas, Parana	107	100.00	—	—	—	—	1.00000	—
Da Silva, '48	Ranikokamekra	Barra do Corda, Maranhão	39	94.87	—	5.13	—	.02599	.97401	—
			280	92.15	1.07	4.64	2.14	.01609	.94960	110.362 < 0.001

TABLE 1 (Continued)

SOURCE	TRIBE	LOCALITY	NO. STUD.	O	A	B	AB	P	q	r	$\chi^2$	P
<i>Paraguai:</i>												
Urizar, '42	Maca	Chaco	111	97.30	0.90	1.80	—	.00451	.00905	.98644	0.011	> 0.90
<i>Argentina:</i>												
Mazza and Franke, '27	Several	Prov. de Salta	120	100.00	—	—	—	—	—	1.00000	—	—
Mazza et al., '33	Chunupi	— <sup>5</sup>	55	100.00	—	—	—	—	—	1.00000	—	—
Mazza, '39	Chunupi	Prov. de Salta	282	95.39	4.26	—	0.35	.02330	.00175	.97495	33.632	< 0.001
Mazza, '39	Matacos	— <sup>5</sup>	78	100.00	—	—	—	—	—	1.00000	—	—
Mazza et al., '33	Matacos	— <sup>5</sup>	135	96.30	3.70	—	—	.01867	—	.98133	—	—
Alvarez, '39	Matacos	— <sup>5</sup>	227	78.85	14.98	3.97	2.20	.08953	.03119	.87928	12.369	< 0.001
Mazza et al., '33	Toba	— <sup>5</sup>	194	98.45	1.55	—	—	.00778	—	.94222	—	—
Paulotti and Alegria, '43	Andinos	Prov. de Jujui	209	94.74	3.83	—	1.43	.02656	.00715	.96629	104.654	< 0.001
Mazza et al., '33	Choroti	Chaco	147	89.12	10.88	—	—	.05597	—	.94403	—	—
Mazza et al., '33	Pillagas	— <sup>5</sup>	46	82.61	17.39	—	—	.09110	—	.90890	—	—
Mazza et al., '33	Colla	— <sup>5</sup>	115	63.48	36.52	—	—	.20326	—	.79674	—	—
<i>Chile:</i>												
Lipschutz et al., '46 <sup>a</sup>	Onas, Yamanas and Alakalufs	Tierra del Fuego	34	100.00	—	—	—	—	—	1.00000	—	—
Sandoval et al., '46 <sup>c</sup>	Mapuches	Prov. de Cautin	205	86.83	8.78	3.41	0.98	.04995	.02215	.92790	5.790	< 0.02
Sandoval and Henckel, '54	Mapuches	Prov. de Cautin	258	79.46	13.56	6.98	—	.07083	.03557	.89360	1.426	> 0.20

<sup>1</sup> One A individual was included in the original article, who however was stated clearly to be of mixed ancestry.

<sup>2</sup> Frimm ('47), found 99% of group O among 78 Guaranis and Caingangs and 23 mestizos studied in Rio Grande do Sul.

<sup>3</sup> It is possible that some of the Camauras and Kalapalos studied by Lima ('50), have been included among Pantin and Junqueira's ('52) subjects.

<sup>4</sup> Da Silva (unpublished), cited by Junqueira and Wishart ('56), obtained the following results among the Carajas: in 113 individuals examined — 104 O, 1 A, 3 B, and 5 AB. The results of Golden ('30) are not included, since they were not confirmed by Junqueira and Wishart ('56) and Da Silva (unpublished).

<sup>5</sup> The locality in which this tribe was studied is not mentioned in the reference consulted.

<sup>6</sup> Rahm's work on the Yamanas ('31) was omitted, since it was not confirmed by Lipschutz et al. ('46).

<sup>7</sup> The results obtained by Rahm ('31) and Onetto and Castillo ('36) on the Mapuches were not included, since they represent the pooling of populations with widely different blood group frequencies. The data is not presented in a sufficiently detailed way to enable a better analysis of it.



With the exception of the works of Sandoval, Henckel, and Givovich ('46), and Sandoval and Henckel ('54), no distinction was made in these studies between the subgroups of A. In the two instances in which data are available, the results obtained were as follows: in the data of Sandoval, Henckel, and Givovich — 17  $A_1$ , 1  $A_2$ , 2  $A_1B$ , and zero  $A_2B$ ; in the sample studied by Sandoval and Henckel only  $A_1$  was found, and no AB individuals were detected. Both studies were made among the Mapuche Indians of Chile.

The data in table 1 are arranged by country, listed from north to south. This subdivision by countries is no doubt artificial, since national boundaries do not correspond to limits of Indian racial distributions, but necessary due to the insufficient amount of data available on the physical anthropology of the living South American Indians. There follows a presentation of the data by individual countries.

*Venezuela.* Only recently have blood group studies been performed in Indian populations in this country, due to the interest which arose as a consequence of the discovery of the Diego blood group (Layrisse and Arends, '56a, '57b). The Caribs from Cachama and S. Clara de Aribi, as well as the Piaroas and Guahibos of the Territorio Amazonas, are all 100% O in the samples studied, but the Guajiros (Arawac) from Ziruma present gene frequencies significantly different from those obtained in the three above-mentioned populations. The  $\chi^2$  for homogeneity (see Neel and Schull, '54, p. 205) in this case is equal to 14.359; with 6 degrees of freedom, P is less than 0.05.

Layrisse, Arends and Sisco ('55) assigned both the Caribs from Cachama and S. Clara, and the Guajiros, to the Brasiliden of von Eickstedt ('34), which corresponds to the Amazonidos of Imbelloni ('38). The latter author, however, considers the Guajiros and Piaroas as Fueguídos. As these two racial groups probably cannot be separated in regard to their ABO blood group frequencies (see the Discussion), the discrepancy is not important in this case. There is the possibility, therefore, that the difference found was due to white admixture

in the Guajiro population, although precautions were taken to avoid the inclusion of individuals of mixed ancestry and, from the description of the authors (Layrisse, Arends and Sisco, '55), this population was not in an advanced state of acculturation.

*Surinam.* Three populations have been studied in this Dutch possession. Collier, Fros and Schipper ('52) in their paper raised the possibility that the anti-A serum used by Kahn ('36) had been spoiled in his long journey, although Kahn (l.c.) mentioned the fact that after returning from the interior he had checked the sera used and found them in good condition. The technique of Collier et al. ('52), on the other hand, is not completely free from criticism.

Imbelloni ('38) includes all the tribes of Surinam among the Amazonidos. A test for homogeneity fails to reveal statistically significant differences among these three populations ( $\chi^2 = 5.474$ ; 4 d.f.;  $P > 0.20$ ).

*Colombia.* A large amount of work has been done in this country in relation to the ABO blood groups. In some cases, however, the degree of white or Negro mixture existent in the populations studied was not always clear. In some cases populations with highly different blood group frequencies due to white or Negro admixture were pooled together. Therefore, a detailed examination of the papers published, and statistical analysis of the partial results presented was necessary, before the tabulation of the results presented in table 1. Whenever it was realized that two or three populations of presumably the same racial background differed significantly in the frequencies of their blood groups due to mixture, those with the higher frequency of 0 were chosen. This, of course, can introduce a bias toward higher frequencies of  $r$  than those actually present in these racial groups, but this probably is inevitable due to the way the data were collected.<sup>3</sup> The interested reader is referred to the original references, for an evaluation of the degree of selection used in the manipulation of these data.

<sup>3</sup> Throughout this paper, the gene frequencies of the genes A, B, and O will be represented by the commonly used letters  $p$ ,  $q$ , and  $r$ , respectively.

As can be seen in table 1, the observed phenotype frequencies fit fairly well the gene frequency estimates given, with the exception of the sample from the Pijao of Ortega ( $\chi^2 = 67.450$ ; 1 d.f.;  $P < 0.001$ ). A test of homogeneity in relation to the Pijao sampled in the regions of Natagaima, Coyaima and Ortega discloses significant heterogeneity among them ( $\chi^2 = 77.865$ ; 4 d.f.;  $P < 0.001$ ), as well as among those of Natagaima and Coyaima (with the exclusion of those from Ortega). In the latter case the  $\chi^2$  is equal to 11.089; with two degrees of freedom the  $P$  value is less than 0.01.

For the comparison of the gene frequencies of the Pijao with those from other tribes, the value obtained in Natagaima was used. There are statistically significant differences in gene frequencies in the populations sampled in Colombia ( $\chi^2 = 74.133$ ; 14 d.f.;  $P < 0.001$ ). A partition of this  $\chi^2$  gives the following results: (a) Differences in  $r$ :  $\chi^2 = 59.145$ ; 7 d.f.;  $P < 0.001$ ; (b) Remainder:  $\chi^2 = 14.988$ ; 7 d.f.;  $P < 0.05$ . Thus, not only the  $r$  frequencies vary significantly in these populations, but the  $p$  and  $q$  frequencies as well.

The different gene frequencies do not present any clear geographical gradient or correlation with linguistic or cultural characteristics. The highest frequency of the gene 0 is seen among the Pijao of Natagaima ( $r = 1.00000$ ), and the lowest among the Sibundoy and Santiagueños ( $r = .93101$ ). The highest frequency of the gene A appears among the Quillacinga ( $p = .03462$ ), and the lowest among the Pijao of Natagaima ( $p = \text{zero}$ ). In regard to the gene B, its highest frequency is found among the Sibundoy and Santiagueños ( $q = .03654$ ), and its lowest again among the Pijao of Natagaima ( $q = \text{zero}$ ). It is probable that at least some of these differences are due to white or Negro admixture. Paez Perez and Freudenthal ('44), by the way, admit the occurrence of "mestizos" in their sample of Sibundoy and Santiagueños, especially in the first ones. It is possible, also, that the assignment of an  $r$  value of 1.00000 to the Pijao represents an oversimplification, in spite of the fact that the sample studied in Natagaima is relatively large (281 individuals examined).

Further speculation concerning the results obtained seems unprofitable now. Only careful studies, in which a high degree of selection of the subjects is made to avoid the occurrence of individuals of mixed ancestry, can throw additional light on the distribution of these genes in the Indian populations of Colombia.

*Ecuador.* The Indian populations of Ecuador are better studied than those of any other country in South America, in relation to the ABO blood groups. Santiana ('44, '47 and '52), in a series of very extensive surveys, was able to study representatives of the great majority of Indian groups living in this country, and Hoffstetter and Martelly ('49) have analyzed and interpreted his results in the light of the available anthropological data. Unfortunately, in four out of the five groups of Andidos studied, the observed phenotype frequencies do not fit the estimated gene frequencies, all four showing a significant excess of AB individuals.

The tribes studied can be placed, according to Hoffstetter and Martelly (1.c.) among Imbelloni's Andidos and Amazonidos (see table 1). The Andidos do not show statistically significant differences among themselves ( $\chi^2=9.793$ ; 8 d.f.;  $P>0.20$ ). The same is true in relation to the Amazonidos ( $\chi^2=2.251$ ; 2 d.f.;  $P>0.30$ ). But when the comparison is made between the Andidos and the Amazonidos (see the weighted estimates and corresponding standard errors of both), it can be seen that the differences are statistically significant at the 1% level. Accordingly, it could be postulated that the Andidos generally possess a relatively high frequency of genes A and B, whereas the Amazonidos would have very low frequencies of these genes or would lack them at all (Hoffstetter and Martelly, '49).

There are two tribes, however, the Colorados and Cayapas, which do not seem to fit this scheme very well. According to their physical types they could be ascribed to the Andidos, but their ABO blood group figures clearly show an Amazonido-like frequency (Santiana, '52). It should be mentioned, however, that their gene frequencies are not significantly different



from those of the Andidos ( $\chi^2 = 8.546$ ; 4 d.f.;  $P > 0.05$ ) — but not different from those of the Amazonidos either. The inclusion of their frequencies among the Andidos does not significantly alter the differences between Andidos and Amazonidos, but following Santiana ('52) they were set apart from both groups in table 1.

*Peru.* Only four studies, to date, were performed in the Peruvian Indians in relation to the ABO blood groups. The values obtained present statistically significant differences among themselves ( $\chi^2 = 50.855$ ; 6 d.f.;  $P < 0.001$ ). A partition of this  $\chi^2$  shows the following results: (a) Differences in  $r$ :  $\chi^2 = 39.122$ ; 3 d.f.;  $P < 0.001$ ; (b) Remainder:  $\chi^2 = 11.733$ ; 3 d.f.;  $P < 0.01$ . Thus, the differences are due not only to the 0 gene, but to the A and B genes as well.

It is difficult to interpret these differences, since all the studies present results in which individuals from different tribes were pooled together. The degree of white admixture in the samples studied was stated by the several authors to be small, therefore it is possible that at least part of these differences are due to varying frequencies of these genes in different tribes.

*Brazil.* A number of Brazilian tribes have been surveyed in relation to the characteristics under consideration. Generally, however, the numbers of individuals studied per tribe were small. The outstanding finding in these studies is the complete lack of representation of the A and B genes in almost the totality of tribes tested. One thousand eight hundred thirty-seven individuals were found to be of group 0 in some 15 tribes studied. The only two exceptions to this picture are the Caingang and Ramkokamekra (see table 1). The differences between these two last mentioned tribes and the remaining are statistically significant ( $\chi^2 = 184.459$ ; 4 d.f.;  $P < 0.001$ ). In both Caingangs and Ramkokamekra, however, a significant amount of white admixture was recognized.

It can be concluded that the Brazilian Indians studied present exclusively or almost exclusively the 0 gene in their populations. Almost all of them can be ascribed to the Amaz-



onidos. The Botocudos and Bororos, however, can be classified as Fueguidos and Pampidos, respectively (Imbelloni, '38).

*Paraguay.* Only one study has been made in the Paraguayan Indians, in relation to the ABO blood groups. Urizar ('42) obtained the following gene frequencies:  $r = .98644$ ;  $p = .00451$  and  $q = .00905$ . These Indians can probably be ascribed to the Pampidos of Imbelloni.

*Argentina.* Almost all the studies performed in this country have been carried out by S. Mazza and his associates. The interesting feature of all these studies is the complete or almost complete absence of the gene B. In the three samples in which this gene is present, the observed phenotypes do not agree with the estimated gene frequencies (see table 1).

There are significant differences in gene frequencies in the two studies of the Chunupis ( $\chi^2 = 29.401$ ; 2 d.f.;  $P < 0.001$ ), as well as in the three Mataco samples studied ( $\chi^2 = 41.446$ ; 4 d.f.;  $P < 0.001$ ). But the two Mataco samples studied by Mazza in 1928 and 1933 do not differ significantly one from the other ( $\chi^2 = 2.932$ ; 2 d.f.;  $P > 0.20$ ). Accordingly, the weighted estimates of these two samples were used as representative of the Matacos. The Chunupi tested in 1933 were used as representative of the Chunupi in the comparison with the other tribes.

There is significant heterogeneity among the several tribes tested in Argentina ( $\chi^2 = 206.148$ ; 14 d.f.;  $P < 0.001$ ). These differences are significant in regard to the gene O and A as well, as can be seen by the following partition of  $\chi^2$ : (a) Differences in  $r$ :  $\chi^2 = 186.101$ ; 7 d.f.;  $P < 0.001$ ; (b) Remainder:  $\chi^2 = 20.047$ ; 7 d.f.;  $P < 0.01$ . The gene O has its maximum frequency of 1.00000 in the sample of several tribes of the Provincia de Salta tested by Mazza and Franke ('27) and the Chunupis tested by Mazza, Schürmann and Gutdeutsch ('33); and its lowest frequency among the Colla (.79674). The A gene shows obviously an inverse relationship to the frequencies of O, reaching its highest frequency among the Colla and lacking completely among the Chunupi and Chiriguano, Chaguancos and Chamacocos tested.

The great majority of the tribes studied (with the exception of the Andidos tested by Paulotti and Alegria, '43, and the Chiriguanos tested by Mazza and Franke, '27) can probably be placed among the Pampidos. The observed variation in gene frequencies is not correlated with the degree of linguistic relationship existent among the tribes. The Toba, for instance, a Guaikuru-speaking tribe, shows a gene frequency more similar to the Matacos than the Choroti, in spite of the fact that these two latter tribes belong to the same linguistic group.

*Chile.* The data on Chilean Indians are by no means abundant. In table 1 are tabulated the results in the three populations from which reliable data is available. The two Mapuche samples do not show statistically significant differences among themselves ( $\chi^2 = 3.222$ ; 2 d.f.;  $P > 0.10$ ). The differences between them and the Onas, Yamanas and Alakalufs tested by Lipschutz, Mostny and Robin ('46) are, however, statistically significant ( $\chi^2 = 6.311$ ; 2 d.f.;  $P < 0.05$ ). These dissimilarities probably can be explained by white admixture in the Mapuche sample (recognized by Sandoval and Henckel, '54). But differences not due to white admixture cannot be completely ruled out, since the Onas can be placed among the Pampidos, the Yamanas and Alakalufs among the Fuegideos, and the Mapuches among the Andidos (Imbelloni, 1938; see also Biasutti, 1957, p. 327).

### *The MN blood groups*

Table 2 shows the limited data available for the MN blood groups of South American Indian populations. The table shows phenotype and gene frequency estimates, as well as  $\chi^2$  and P values for each sample concerning the fit of the observed phenotype frequencies with the corresponding gene frequencies. As can be seen, with one exception only, all the observed phenotypes agree fairly well with the gene frequency estimates.

The differences between the two Mapuche samples are not statistically significant ( $\chi^2 = 1.201$ ; 1 d.f.;  $P > 0.20$ ). But, as expected, there are statistically significant differences among

TABLE 2

*MN blood group phenotype and gene frequency estimates in Indian populations from several South American countries.  $\chi^2$  and P values for the fit between the observed phenotypes and those expected for the gene frequencies given are shown in the two last right hand columns*

SOURCE	TRIBE	LOCALITY	NO. STUD.	GENE FREQUENCIES					$\chi^2$	P
				MM	MN	NN	m	n		
<i>Peru:</i>										
San Martin, '51	Not specified	Dep. de Junin	200	44.50	45.50	10.00	.67250	.32750	0.216	> 0.50
<i>Brazil:</i>										
Da Silva, '48	Ranokamekra	Maranhão	236	39.41	50.85	9.74	.64830	.35170	3.127	> 0.05
Ottensooser and Pasqualin, '49	Caiuas	Mato Grosso	134	79.85	19.40	0.75	.90909	.09091	0.804	> 0.30
Bioeca and Ottensooser, '44	Tucanos	Amazonas	68	48.53	42.65	8.82	.69853	.30147	0.011	> 0.90
<i>Argentina:</i>										
Mazza, '39	Chunupis	Chaco	282	81.91	11.35	6.74	.87589	.12411	64.530	< 0.001
<i>Chile:</i>										
Henckel et al., '41	Mapuches	Prov. de Cautin	100	57.00	34.00	9.00	.74000	.26000	1.356	> 0.20
Sandoval and Henckel, '54	Mapuches	Prov. de Cautin	144	47.22	44.45	8.33	.69444	.30556	0.323	> 0.50

TABLE 3

*MNS blood group phenotype and gene frequency estimates in two South American Indian populations*

SOURCE	TRIBE	LOCALITY	NO. STUD.	MS	NS	MNS	Ms	Ns	MNs	GENE FREQUENCIES		
										MS	Ms	Ns
<i>Brazil:</i>												
Pantin and Junqueira, '52	Several	State of Mato Grosso	74	10.81	—	47.30	8.11	1.35	32.43	—	—	—
<i>Chile:</i>												
Sandoval and Henckel, '54	Mapuches	Prov. de Cautin	59	28.81	6.78	28.81	22.03	1.70	11.87	.32986	.38194	.18301

them and the other tribes tested ( $\chi^2 = 128.784$ ; 5 d.f.;  $P < 0.001$ ). These differences, however, do not agree well with the degree of racial relationship which exist between these tribes. Thus, the highest and lowest values of the *m* gene were obtained respectively among the Ramkokamekra and Caiuas, both of which are from the Amazonido group of Imbelloni. The low frequency of the *m* gene among the Ramkokamekra can probably, however, be explained by white admixture.

### *The MNS blood groups*

Only two populations of South American Indians have been tested also with the S antisera, besides the more common anti-M and anti-N reagents. The results are presented in table 3. As the Brazilian Indian phenotype frequencies do not fit any gene frequency estimate, only the Mapuche sample will be considered. Their gene frequencies are quite different from those obtained for North American and Canadian Indians and for Eskimo samples (cf. Mourant, '54).

### *The Rh blood groups*

Five samples of South American Indians have been tested with anti-D only (table 6). Of these, three presented 100% Rh positive persons. The six Rh negative persons obtained among the Mapuches of Chile and Guajiros of Venezuela can probably be accounted for as a result of white admixture.

Two populations of Brazilian Indians have been tested with anti-C, anti-D, and anti-E (table 4). The differences between their chromosome frequencies are not significant ( $\chi^2 = 0.400$ ; 2 d.f.;  $P > 0.80$ ).

Two other populations have been tested with anti-C, anti-D, anti-E and anti-c (table 5). They also, do not present significant differences among themselves ( $\chi^2 = 7.763$ ; 3 d.f.;  $P > 0.05$ ).

TABLE 4

*Rh* blood group phenotype and chromosome frequency estimates in two Brazilian Indian populations. Samples tested with anti-C, anti-D, and anti-E

SOURCE	TRIBES	LOCALITIES	NO. STUD.	CDE	CDee	ccDE	CHROMOSOME FREQUENCIES	
							ODe	cDe
<i>Brazil:</i>								
Ottensooser and Pasqualin, '49	Bororós	State of Mato Grosso	103	59.22	23.30	17.48	.52938	.47062
Ottensooser and Pasqualin, '49	Chinua	State of Mato Grosso	135	57.04	22.22	20.74	.50744	.49256

TABLE 5

*Rh* blood group phenotype and chromosome frequency estimates in two South American Indian populations. Samples tested with anti-C, anti-D, anti-E, and anti-c

SOURCE	TRIBE	LOCALITY	NO. STUD.	CHROMOSOME FREQUENCIES									
				CcDee	CcDE	cCDe	cCDE	cde	cDe	ccDee	ccDE	CDe	cDe
<i>Brazil:</i>													
Pantin and Junqueira, '52	Several	State of	73	5.48	30.14	43.83	12.33	8.22	—	.05105	.58595	.29726	.06574
		Mato Grosso											
<i>Chile:</i>													
Sandoval and Henckel, '54	Mapuches	Prov. de Cautin	258	1.55	43.80	29.85	8.14	12.40	4.26	.01122	.63223	.23859	.11796



*Other blood groups*

Phenotype and gene frequency estimates of other blood groups than those discussed above are listed in table 6. Let us first consider the *Diego blood group* frequencies (Layrisse and Arends, '56a and '57b). The differences between the Caribs from Cachama and Santa Clara de Aribi are statistically significant ( $\chi^2 = 7.583$ ; 1 d.f.;  $P < 0.01$ ). These differences are however probably due only to sampling, since, as stated by Layrisse, Arends and Sisco ('55), they are due to the fact that two large families studied in Santa Clara were Diego negative. The frequency obtained in Cachama was taken as representative of the Caribs for the comparison with the other tribes. There are statistically significant differences in the frequency of this blood group system in the several South American tribes tested ( $\chi^2 = 61.826$ ; 5 d.f.;  $P < 0.001$ ). The postulated  $Di^a$  gene is found in high frequencies among the Brazilian tribes ( $Di^a = .26400$  and  $.20069$  among the Caingangs and Carajas, respectively), its frequency lowering in the following order in the Venezuelan tribes: Caribs, Guahibos, Piaroas and Guajiros. The Guajiros present the lowest frequency:  $Di^a = .02666$ .

Two populations have been studied for the *Duffy blood groups*, both consisting of Brazilian Indians living in northern Mato Grosso. Despite their geographic proximity and possible close racial relationship, the differences between them are statistically significant ( $\chi^2 = 37.231$ ; 1 d.f.;  $P < 0.001$ ). Among the Camaiura and Kalapalo, Pantin and Junqueira ('52) were unable to find any individual  $Fy(a+)$ , while Junqueira and Wishart ('56) found 23 individuals  $Fy(a+)$  among 55 Carajas studied.

Pantin and Junqueira ('52) found 23.29% *Kell* positives among 73 Brazilian Indians. Recently Chown and Lewis ('57) reported unpublished results of Dr. Fred H. Allen, Jr.: in about 300 Peruvian Indians he could not find any *Kell* positive. Chown and Lewis (l.c.) believe that the presence of the anti-

TABLE 6

*Rh* blood group (tests with anti-*D* only), and other blood group phenotype and gene frequency estimates in several South American Indian populations

SOURCE	TRIBES	LOCALITIES	NO. STUD.	PHENOTYPES		GENOTYPES	
				<i>Rh</i> +	<i>Rh</i> -	<i>D</i>	<i>d</i>
<i>Rh</i> , <sup>1</sup> <i>Venezuela</i> :							
Layrisse and Arends, '57a	Caribs	Cachama and Santa Clara	169	100.00	—	1.00000	—
Layrisse and Arends, '57a	Guajiros	Ziruma	152	98.02	1.98	.85929	.1407
Layrisse (unpublished)	Piaroas	Terr. Amazonas	24	100.00	—	1.00000	—
Layrisse (unpublished)	Guahibos	Terr. Amazonas	76	100.00	—	1.00000	—
<i>Chile</i> :							
Sandoval et al., '46	Mapuches	Prov. de Cautin	205	98.54	1.46	.87917	.1208
				<i>Di</i> (a+)	<i>Di</i> (a-)	<i>Di</i> <sup>a</sup>	<i>Di</i> <sup>b</sup>
<i>Diego, Venezuela</i> :							
Layrisse et al., '55	Caribs	Cachama	121	35.54	64.46	.19713	.8028
Layrisse et al., '55	Caribs	Santa Clara	49	14.29	85.71	.07420	.9258
Layrisse et al., '55	Guajiros	Ziruma	152	5.26	94.74	.02666	.9733
Layrisse and Arends, '56b	Piaroas	Terr. Amazonas	24	12.50	87.50	.06459	.9354
Layrisse and Arends, '56b	Guahibos	Terr. Amazonas	76	14.47	85.53	.07518	.9248
<i>Brazil</i> :							
Junqueira et al., '56	Caingang	State of Parana	48	45.83	54.17	.26400	.7360
Junqueira et al., '56	Carajas	State of Mato Grosso	36	36.11	63.89	.20069	.7993
				<i>Fy</i> (a+)	<i>Fy</i> (a-)	<i>Fy</i> <sup>a</sup>	<i>Fy</i> <sup>b</sup>
<i>Duffy, Brazil</i> :							
Pantin and Junqueira, '52	Several	State of Mato Grosso	73	—	100.00	—	1.0000
Junqueira and Wishart, '56	Carajas	State of Mato Grosso	55	41.82	58.18	.23724	.76276
				<i>P</i> +	<i>P</i> -	<i>P</i>	<i>p</i>
<i>P, Brazil</i> :							
Pantin and Junqueira, '52	Several	State of Mato Grosso	73	41.10	58.90	.23254	.76746
				<i>Lu</i> (a+)	<i>Lu</i> (a-)	<i>Lu</i> <sup>a</sup>	<i>Lu</i> <sup>b</sup>
<i>Lutheran, Brazil</i> :							
Pantin and Junqueira, '52	Several	State of Mato Grosso	73	16.44	83.56	.08589	.91411
				<i>K</i> +	<i>K</i> -	<i>K</i>	<i>k</i>
<i>Kell, Brazil</i> :							
Pantin and Junqueira, '52	Several	State of Mato Grosso	73	23.29	76.71	.12416	.87584

<sup>1</sup> San Martin ('51) presented data on 200 Indians from Peru, tested with anti-*D* and anti-*C* + *D* but there seems to be a mistake or typographical error in the presentation of his findings.

gen K in North American Indians or Eskimos indicates the presence of white genes in the population.

The *P* and *Lutheran blood groups* have been studied in only one population each.

#### DISCUSSION

Several racial classifications of South American Indians have been proposed in the last century (review in Imbelloni, '38). Imbelloni's own classification is the most recent one, and in many ways the most satisfactory. It is, however, by no means perfect; several restrictions can and have been made to his classification (cf. Newmann, '51), but as the last mentioned author pointed out, the limited amount of data which prevented Imbelloni from fully validating his synthesis, limits his critics in negating it. The present paper attempts to see if the serological results agree with Imbelloni's classification. As shown above, the picture is by no means simple. The comparison is made more difficult because very little information concerning the physical anthropology of some of the tribes studied is available (see, for instance, Steggerda, '50), and in the great majority of the cases it is difficult to separate the differences due to racial divergence from those simply due to white or Negro admixture. Nevertheless, some basic correlations can perhaps be suggested. Thus, we can describe some of Imbelloni's racial groups, on the basis of the available ABO serological data, as follows (see fig. 1): (a) *Amazonidos*: almost exclusively O genes; A and B lacking or extremely rare; (b) *Andidos*: high frequency of O, fair amounts of A and B, with A more frequent than B; (c) *Pampidos*: high frequency of O, fair amount of A, almost complete lack of B; (d) *Fueguidos*: perhaps almost exclusively O.

The serological characterization of Pampidos and Fueguidos is highly tentative, being supported only by the limited amount of data supplied by the studies of Mazza and his associates in Argentina and the works of Lipschutz, Mostny and Robin ('46) in Chile, Martins and Bastos ('35) in Brazil, and Layrisse et al. ('55) in the Piaroas of Venezuela. The characterization of the Amazonidos and Fueguidos seem to be better

documented. But there are exceptions to these generalizations, some of which have already been discussed in the preceding section. As they stand now, they could at best be presented as a working hypothesis.

By necessity, the serological characterization had to be confined to the ABO blood groups, since very little is known about the other blood groups of the South American Indians. The danger of such oversimplification is obvious. Tribes such as the Piaros and Guahibos of Venezuela, undistinguishable from the Caribs of the same country by their ABO blood group frequencies, can however be easily separated from them by their Diego blood group frequencies. The same is true in relation to the Caiuas and Tucanos of Brazil, when their ABO and MN blood group frequencies are compared.

Several samples tabulated in the present work presented phenotype frequencies which did not fit the estimated gene frequencies. The most common explanation for such discrepancies is the use of inadequate sera. It is however seldom realized that several other factors can influence the  $\chi^2$  thus obtained. The model utilized for the calculation of the gene frequencies assumes random mating, absence of selection, genetic equilibrium, and an infinitely large population. It is evident that in almost the totality of the cases studied one or more of these requirements was not fulfilled. It is well known that South American Indians, as any other human population, do not marry at random, and almost always have strict conventions as to the mate they may choose. On the other hand, our concepts of the extent to which the various blood groups are subject to selective factors are now undergoing considerable revision (see, for instance, McConnell, '56, for data concerning the ABO locus). With rare possible exceptions, also, human populations are definitely not in genetic equilibrium at present. This is particularly true for the tribes under consideration. And nothing is more far from reality than the idea of an infinitely large population, when we are actually studying small Indian communities. Another possible cause for these discrepancies is inadequate sampling, with the in-

clusion of a considerable number of genetically related individuals. Thus, it would be highly desirable that future surveys would include data on the mating system of the tribes under study, the degree of consanguinity of the individuals studied, and the effective population number of these populations. This, of course, would require much more time and energy than is now devoted to these surveys, but would greatly increase their value.

Another point which should be stated clearly in future investigations is the amount of hybridization which took place and was taking place at the time the survey was made in the population under study, not only with whites and Negroes, but among the different Indian tribes as well. This also, is a kind of data difficult to get, but a clear indication of the degree of admixture can be obtained by getting the frequency of mestizos in the locality, family histories, and historical data.

The writer believes that a much better picture of the complex racial interrelations of the South American Indians can be obtained, if the several factors discussed above are considered.

#### SUMMARY

A review of the South American Indians' blood groups was made. The data was analyzed statistically, and the results interpreted in terms of the available anthropological information.

In a general way, it can be said that the ABO blood group frequencies can be correlated with Imbelloni's ('38) racial groups in the following way: (a) the *Amazonidos* have almost exclusively O genes; the A and B genes are extremely rare or non-existent; (b) the *Andidos* present a high frequency of O and fair amounts of A and B, with A more frequent than B; (c) the *Pampidos* have a high frequency of O, fair amount of A, and almost none B; (d) the *Fueguidos* perhaps had on earlier times almost exclusively O.

The two last generalizations are not as well documented as the two first. It is important to note also that several ex-



ceptions to these rules can be found. It is believed, however, that they constitute a good working hypothesis.

#### ACKNOWLEDGMENTS

The writer wishes to acknowledge his gratitude to Prof. James V. Neel, Chairman of the Department of Human Genetics of the University of Michigan, for his hospitality and suggestions in the preparation of the manuscript; and to Dr. James N. Spuhler, also for suggestions regarding the manuscript.

#### LITERATURE CITED

- ALVAREZ, A. G. 1939 Comprobaciones biológicas en aborígenes argentinos — Consideraciones sobre los grupos sanguíneos de los Matacos. Comisión Honoraria de Reducciones de Indios. Buenos Aires. Publ. no. 6: 25-34.
- ARCE LARRETA, J. 1930 Doseientas determinaciones de grupos sanguíneos en los indios del norte del Peru. An. Hosp., Lima, 3: 74-77.
- ARCILA VELEZ, G. 1943 Grupos sanguíneos entre los indios Pacz. Rev. Inst. Etnol. Nac., Bogota, 1: 7-14.
- 1946 Los "Caramanta." Univ. Antioquia, 20: 445-452.
- BERNSTEIN, F. 1930 Fortgesetzte Untersuchungen aus der Theorie der Blutgruppen. Zeitschr. f. Abstamm. — u. Vererbungslehre, 56: 233-273.
- BIASUTTI, R. 1957 Le razze e i popoli della terra. 2nd. edition. Unione Tipografica — Editrice Torinese, Torino.
- BIOCCA, E., AND F. OTTENSOOSER 1944 Estudos etno-biológicos sobre os indios da região do Alto Rio Negro — Amazonas. I. — Grupos sanguíneos comuns e fatores M e N. Arqu. de Biol., 28: 1-8.
- BOYD, W. C. 1939 Blood groups. Tabulae Biologicae, 17: 113-240.
- 1950 Blood groups of South American Indians. In Handbook of South American Indians, 6. Bull. Bureau of Amer. Ethnol., 143: 91-95.
- CHOWN, B., AND M. LEWIS 1957 The Kell antigen in American Indians. Amer. J. Phys. Anthropol., 15: 149-156.
- COLLIER, W. A., J. FROS AND J. F. A. SCHIPPER 1952 Blood groups of some American Indian settlements. Docum. Med. Geogr. Trop., 4: 225-226.
- DA SILVA, E. 1948 Grupos sanguíneos comuns e fatores M e N em indios Canella (Ramkokamekra) do Maranhão. Rev. Mus. Paul., 2: 271-274.
- 1949 Blood groups of Indians, Whites and White-Indian mixtures in southern Mato Grosso, Brazil. Amer. J. Phys. Anthropol., 7: 575-585.
- DUQUE GOMEZ, L. 1944 Grupos sanguíneos entre los indígenas del Departamento de Caldas. Rev. Inst. Etnol. Nac., Bogotá, 1: 623-653.
- FERNANDES, J. L. 1939 Notas hemato-antropológicas sobre os Caingangues de Palmas. Rev. Med. Paraná, 8: 1-8.

- FRIMM, C. E. 1947 A drepanocitose. Clínica e hematologia da anemia drepanocítica e da drepanocitemia. Doctorate Thesis, School of Medicine, Pôrto Alegre, Brazil.
- GOLDEN, G. 1930 Distribution of blood groups in South American Indians. *Lancet*, ii: 278-279.
- HENCKEL, K. O., A. CASTELLI AND J. DAL BORGIO 1941 Algunas observaciones acerca de la proporción de los grupos sanguíneos M y N de los indios Mapuches. *Bol. Soc. Biol. Concepcion*, 15: 37-41.
- HOFFSTETTER, R., AND J. MARTELLY 1949 Características serológicas (sistema ABO) de los indios del Ecuador (Estudio crítico de los resultados experimentales de A. Santiana). *Ciencia*, 9: 101-118.
- IMBELLONI, J. 1938 Tabla clasificatória de los Indios. Regiones biológicas y grupos raciales humanos de America. *Physis*, 12: 229-249.
- JUNQUEIRA, P. C., AND P. J. WISHART 1956 Blood groups of Brazilian Indians (Carajás). *Nature*, 177: 40.
- JUNQUEIRA, P. C., P. J. WISHART, F. OTTENSOOSER, R. PASQUALIN, P. L. FERNANDES AND H. KALMUS 1956 The Diego blood factor in Brazilian Indians. *Nature*, 177: 41.
- KAHN, M. 1936 Blood grouping of 336 Upper Aucas Bush Negroes and 70 Alkuyana Indians in Dutch Guiana. *J. Immunology*, 31: 377-385.
- LAYRISSE, M., AND T. ARENDS 1956a High incidence blood group found in Venezuelan Indians. *Science*, 123: 633.
- 1956b The Diego blood factor in Chinese and Japanese. *Nature*, 177: 1083-1084.
- 1957a The Diego blood factor in Negroid populations. *Nature*, 179: 478-479.
- 1957b The Diego system—steps in the investigation of a new blood group system. Further studies. *Blood*, 12: 115-122.
- LAYRISSE, M., T. ARENDS AND R. D. SISCO 1955 Nuevo grupo sanguíneo encontrado en descendientes de indios. *Acta Med. Venez.*, 3: 132-138.
- LEHMANN, H., A. C. ARAUJO AND M. CHAVES 1946 Grupos sanguíneos entre los indios Kwaiker. *Bol. Arqueol.*, Bogotá, 2: 227-230.
- LEHMANN, H., L. DUQUE AND M. FORNAGUERA 1943 Grupos sanguíneos entre los indios Guambiano-Kukonuko. *Rev. Inst. Etnol. Nac.*, Bogotá, 1: 197-208.
- LIMA, P. E. DE 1950 Grupos sanguíneos dos indios do Xingu. *Bol. Mus. Nac.*, Rio de Janeiro, 11: 1-4.
- LIPSCHUTZ, A., G. MOSTNY AND L. ROBIN 1946 The bearing of ethnic and genetic conditions on the blood groups of three Fuegian tribes. *Am. J. Phys. Anthropol.*, 4: 301-322.
- MARROQUIN, J. 1946 Particularidades antropológicas del indigena puneño. *Rev. Mus. Nac.*, Lima, 15: 13-32.
- MARTINS, A. V., AND T. BASTOS 1935 Sobre a distribuição dos grupos sanguíneos entre os indios Botocudos do Rio Doce. *Brasil Médico*, 49: 108-109.
- MAZZA, S. 1939 Los factores M y N en sangre de indígenas del Chaco argentino comparados con los de nativos de Buenos Aires. *Soc. Arg. de Patol. Reg.*, 9a. Reunión, Mendoza, 3: 1916-1918.

- MAZZA, S., AND I. FRANKE 1927 Grupos sanguíneos de indios y de autóctonos del norte argentino. *Prensa Med. Arg.*, 14: 408-409.
- MAZZA, S., K. SCHÜRMANN AND H. GUTDEUTSCH 1933 *apud* Steffan, P., and S. Wellisch 1936 Die geographische Verteilung der Blutgruppen. *Z. für Rassenphysiologie*, 8: 38-47.
- MC CONNELL, R. B. 1956 Selection and the ABO blood group locus. *Ann. New York Acad. Sci.*, 65: 12-25.
- MOURANT, A. E. 1954 The distribution of the human blood groups. Charles C Thomas, Springfield.
- NEEL, J. V., AND W. J. SCHULL 1954 Human Heredity. University of Chicago Press, Chicago.
- NEWMANN, M. T. 1951 The sequence of Indian physical types in South America. *In* Papers on the Physical Anthropology of the American Indian, The Viking Fund, Inc., New York.
- ONETTO, A. E., AND F. J. CASTILLO 1930 Sobre grupos sanguíneos en los araucanos. *Rev. Inst. Bact., Chile*, 1: 17-24.
- OTTENSOOSER, F., AND R. PASQUALIN 1949 Blood types of Brazilian Indians (Mato Grosso). *Amer. J. Hum. Genet.*, 1: 141-155.
- PAEZ PEREZ, C., AND K. FREUDENTHAL 1944 Grupos sanguíneos entre los indios Sibundoy, Santiagueños, Kwaiker, e indios e mestizos de los alrededores de Pasto. *Rev. Inst. Etnol. Nac., Bogotá*, 1: 411-415.
- PANTIN, A. M., AND P. C. JUNQUEIRA 1952 Blood groups of Brazilian Indians. *Amer. J. Phys. Anthropol.*, 10: 395-405.
- PAULOTTI, O. L., AND L. G. ALEGRIA 1943 Grupos sanguíneos de los nativos de la Puna Jujeña. *An. del Mus. Arg. de Cienc. Nat.*, 41: 21-28.
- RAHM, G. 1931 Los grupos sanguíneos de los Araucanos (Mapuches) y de los Fueguinos. *Invest. y Prog., Madrid*, 5: 160.
- REICHEL-DOLMATOFF, A., AND G. REICHEL-DOLMATOFF 1944 Grupos sanguíneos entre los indios Pijao del Tolima. *Rev. Inst. Etnol. Nac., Bogotá*, 1: 507-520.
- RIBEIRO, L., W. BERARDINELLI AND E. M. ROITER 1935 Grupo sanguíneo dos indios Guarany's. *Arch. Med. Leg. Ident.*, 5: 59-65.
- SANDOVAL, L., AND C. HENCKEL 1954 The ABO, MNS and Rh-Hr blood groups of the Mapuche Indians of Cautin Province, Chile. *Human Biology*, 26: 324-329.
- SANDOVAL, L., C. O. HENCKEL AND L. GIVOVICH 1946 Grupos, subgrupos y factores Rh sanguíneos en los indios Mapuches de la Provincia de Cautin. *Notas Mus. la Plata, 11, Antrop.*, 35: 283-299.
- SAN MARTIN, M. 1951 Equipos sanguíneos y factor Rh en un grupo de nativos del Departamento de Junin. *An. Fac. Med. Lima*, 34: 276-279.
- SANTIANA, A. 1944 Los grupos sanguíneos de los indios del Ecuador. *Comunicación preliminar. Notas Mus. la Plata*, 9, *Antrop.*, 30: 431-438.
- 1947 Los grupos sanguíneos de los indios del Ecuador. *Comunicación definitiva. Impr. de la Universidad, Quito.*
- 1952 Los indios del Ecuador y sus características serológicas. *Terapia*, 10: 13-18.

- STEGGERDA, M. 1950 Anthropometry of South American Indians. *In Handbook of South American Indians*, 6. Bull. Bureau Amer. Ethnol., 143: 57-69.
- TAYLOR, G. L., AND A. M. PRIOR 1938 Blood groups in England. II. — Distribution in the population. *Ann. Eugen.*, 8: 356-361.
- URIZAR, R. 1942 Grupos sanguíneos de autóctonos del Chaco Paraguayo. *Amer. Indig.*, 2: 49-50.
- VON EICKSTEDT, E. F. 1934 Rassekunde und Rassengeschichte der Menschheit. Ferdinand Enke Verlag, Stuttgart.
- WEISS, P. 1948 Estudio sobre los lamistas; su grupo sanguíneo; algunas pruebas psico-técnicas. *Rev. Mus. Nac., Lima*, 18: 19-41.

## ADDENDUM

After this manuscript was submitted, the author encountered a paper by Arcila Velez, dealing with the ABO blood groups of the Catio Indians from Colombia (*Boletín del Instituto de Antropología*, Vol. 1 (1): 65-79; 1953). He studied 129 individuals from Dobeiba and Rioverde, in the Department of Antioquia, and found that 118 were O, 2 A and 9 B. The gene frequencies here are:  $r = .95668$ ,  $q = .03554$  and  $p = .00778$ , with a  $\chi^2$  of 6.569 (1 d. f.,  $P < 0.02$ ). These figures are significantly different from those obtained by the same author (Arcila Velez, '46; see table 1) among the Caramanta, who belong to the Catio group ( $\chi^2 = 9.518$ ; 2 d. f.;  $P < 0.01$ ).

Arcila Velez suggests that the relatively high frequency of the B gene in the Catio sample was perhaps due to Negro admixture. The results do not contradict the working hypothesis presented here.





# SEX DIFFERENCES IN THE FOETAL PELVIS

BARBARA J. BOUCHER

*Department of Anatomy, Washington University School of  
Medicine, St. Louis,<sup>1</sup> London Hospital  
Medical College, London*

FOUR FIGURES

## INTRODUCTION

To obtain the most accurate estimate possible of any parameter of an individual from his skeleton, it is important to apply formulae derived from the appropriate racial group. For this reason, the study of sex differences in the foetal sciatic notch has been extended to Negro foetuses, by a method previously used in British White foetuses (Boucher '55).

Villemin ('37) and Lazorthes and Lhez ('39) found sex differences in the width of the notch in adults, while Letterman ('41) found sex differences in both dimensions. Comparison of the growth changes in the foetus of the width and depth of the sciatic notch with age between males and females, has therefore been made.

Washburn ('48) measuring an ischium pubis index, based on the methods described by Schultz ('30), on which the present study is also based, has found a significant increase in the size of the adult female pubis which, in conjunction with the work of Reynolds ('45), whose studies on immature material show no such sex differences, lead him to suggest that this increase occurs at puberty. He also suggests that this growth is responsible for the increased size of the subpubic angle of the adult female pelvis. Verneau (1875) and Thom-

<sup>1</sup> The bulk of this work was done during the tenure of a Research Fellowship in Anatomy at Washington University School of Medicine, St. Louis, during leave of absence from the London Hospital Medical College.

son (1899) describe larger subpubic angles in the female than in the male foetus. Investigation of the foetal pubis by comparable methods has, therefore been carried out.

#### MATERIAL AND METHODS

Stillbirths of 96 American Negroes and of 33 American Whites as acquired by the Department of Anatomy, Washington University School of Medicine, from the Missouri State Anatomical Board were used. Gestation age had been recorded in 56 of the Negro specimens.

These foetuses had been preserved from two weeks to eight months by refrigeration, and were permitted to thaw at room temperature for about twelve hours before the crown rump length was measured and dissection begun. Specimens found to be abnormal were not used. No soft tissue measurements were made on those specimens in which decomposition or dessication had taken place.

The crown rump length was measured once on each foetus. The femora were dissected out entire, and the maximum length from the head to the medial condyle was measured with sliding calipers. The femora were then placed immediately into 5% formalin in sufficient volume to avoid distortion due to crowding. The pelvis was removed intact and the fibrous tissue dissected away from the perichondrium in areas involving points from which measurements were to be made.

The sub-pubic angle was measured with the pelvis placed so that the ischial tuberosities and the inferior end of the coccyx were resting on a horizontal surface. The lower border of the symphyseal region of the pelvis is difficult to define without damaging the cartilage, but the lower portion of the inferior ramus of the pubis has a straight medial border. It was this which was considered to be the side of the angle. The transparent measuring instrument was a protractor with an adjustable arm. The fixed portion was superimposed on the straight portion of the medial border of the inferior ramus of one side, and the adjustable arm located over the equivalent site on the other side.

There has been much discussion about the choice of a point from which the lengths of the ischium and pubis should be measured. The difficulties in the adult are great since cotyloid bones have been assimilated into the acetabulum and the "suture" lines obliterated. In the foetus, where the relation of the bony centres to the acetabulum can be seen by transillumination, or on suitable X-Rays, it is possible to find a definable point for the measurement of ischium and pubis lengths. The attachment of the ligamentum teres to the acetabulum (i.e. the inner edge of the articular cartilage) takes the form of a trefoil in 97.5% of this material. The middle of these three lobes has either an oval or an oblong shape and, therefore, has either one or two obvious angulations. The anterior edge of the inferior end of the bony ilium was found to be crossed by the apex of the oval, or the anterior of the two points of the oblong middle lobe, when the trans-illuminated joint surface was viewed with the acetabular labrum at right angles to the line of vision. This point is referred to below as A (see fig. 1).

The pubic length was taken as the distance from A to the mid-point of the pubic symphysis, i.e., in the mid-line of the pelvis, and mid-way between the top and the bottom of the cartilage of the pubic symphysis. (B on fig. 1.)

The Ischial length was taken with the pelvis held with one lateral aspect towards the observer. When the two ischial tuberosities appeared as one, (viewed with one eye at the level of the hip joint) one end of the calipers was held at the point A and the other end was moved to lie along the projection of the line joining A and the anterior superior iliac spine. Where this line crossed the ischial tuberosity was taken as the end of the ischium and the distance between the point of its crossing (C, on fig. 1) and A, was considered to be the length of the ischium.

These measurements were reproducible on each specimen before fixation. After the measurements had been taken, each pelvis, its cavity filled with gauze, was placed in 5% formalin.

The measurements of the femora and pelvis were repeated after a period of not more than three weeks in formalin, and then the bones were macerated in hot water (temperature controlled at 98°F) for eighteen hours, or less, depending on the size of the specimen. The bones were removed from the cartilage and dried at room temperature. Each bone was num-

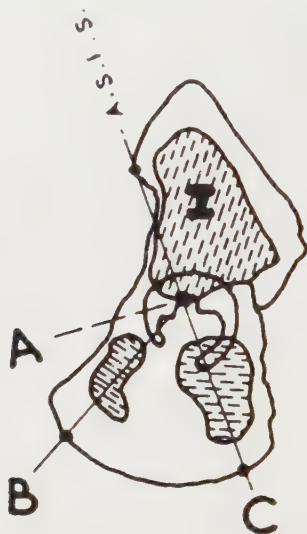


Fig. 1 Tracing of the left side of a foetal pelvis with its x-ray superimposed (ossified portion cross hatched). The acetabular labrum is at right angles to the line of vision, showing the location of fixed points A, B and C in the cartilaginous pelvis. A.S.I.S. = anterior superior iliac spine.

A = Apex of middle lobe of attachment of ligamentum teres, crossing lower edge of bony ilium, I.

B = Mid-point of pubic symphysis. (A.B. = pubis length.)

C = Point where the projection of the line joining A.S.I.S. to A. crosses the ischial tuberosity. (A.C. = Ischium length.)

bered in order to ensure identification of the foetus from which it came. The maximum length of the femoral diaphysis and the greatest lengths of the ischium and pubis along their long axes were measured, using the caliper laid flat, as an anthropometric board. The ischium was laid on its external surface and the pubis on its internal surface for maximum stability and reproducibility of results. The ischium pubis

index was derived by expressing the pubis length as a percentage of the ischium length.

The sciatic notch of each ilium was measured by the following method (Boucher, '55). "Each ilium was laid on its dorsal surface on a flat table and examined with one eye from about 12" above it, and the point of contraflexure was marked with coloured varnish on each side of the notch. This point is the one at which the curvature of the notch changes to that of the contiguous bone edge and can be seen by eye." See fig. 2.

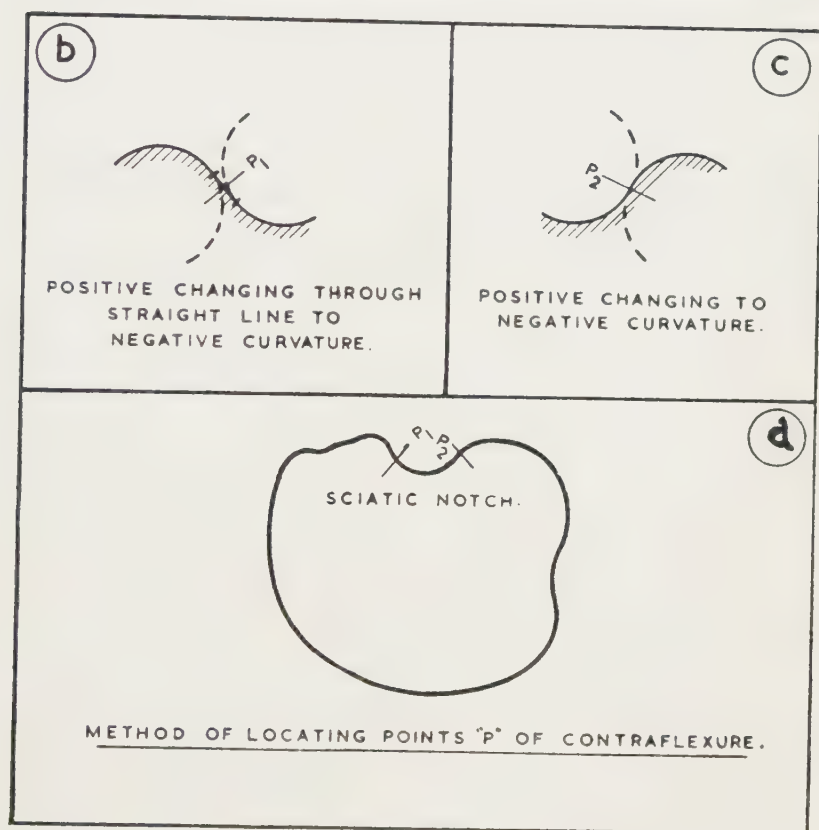


Figure 2

(a) Outline of the ventral surface of a bony ilium to show the sites of the points of contraflexure p. 1 and p. 2.

(b) Diagram to show how p. 1. of diagram (a) was located.

(c) Diagram to show how p. 2. of diagram (a) was located.



"The width between these points was measured by holding the bones with the two marks horizontally aligned against a thin brass taper gauge calibrated in mm and held upright from the table. With the bone held firmly in this position with one hand, the depth was measured by running a second taper gauge . . . down the width scale until it fitted . . . and the bones were repositioned if any shift occurred during measurement."

TABLE 1

*Summary of the data obtained from American Negro  
American White and British White material*

	I/P. Ix. (Cart.)	I/P. Ix. (Bone.)	Subpubic Angle.	Sciatic Notch Index.	
GROUP. N.O.	MEAN. RANGE. S.E.	MEAN. RANGE. S.E.	MEAN. RANGE. S.E.	MEAN. RANGE. S.E.	% CORRECT.
WHITE. G.B. M. 46				4.57 3.65-6.0 .091	80.43
WHITE. G.B. F. 61				5.64 4.0-7.3 .096	88.52
WHITE. U.S.A. M. 19	95.25 86-109 1.45	74.2 57.5-86 2.93	69 63 114 13.96	4.81 3.9-6.0 .436	57.8
WHITE. U.S.A. F. 14	96.1 89-104 1.47	78.28 61-93 3.57	91.9 52 85 2.04	5.41 4.9-6.68 .23	71.4
NEGRO. U.S.A. M. 49	95.54 85-116 .84	73.26 33-95 1.18	70.4 53 100 2.23	4.84 3.38-6.8 .0085	73.3
NEGRO. U.S.A. F. 47	99.0 83-113 .95	73.74 23-95.5 2.92	85.95 59 108 2.84	5.81 4.35-8.77 .021	95.1

Showing the means and the range of the values obtained for the Ischium Pubis Index, in both Cartilage and Bone, the Subpubic angles and the Sciatic Notch Indices for Males and Females of British White, American White and American Negro material. The Standard Error (S.E.) of each mean is given. The percentage of each group of foetuses that were correctly sexed by the Sciatic Notch Index is also given. Abbreviations: C.R. = Crown Rump Length; I = Ischium Length; P = Pubis Length; Cart. = Cartilaginous; Ix = Ischium-Pubis Index; Av. = Average.

Measurements of the width and depth of the sciatic notch were made on two separate occasions with the sex and race of the foetus and the previous measurements unknown to the observer. The average of the sciatic notch indices from each bone has been recorded. Since there were no differences obtained at the second measurement that would place a bone in a different sexual group from the one in which it had been placed at the first measurement, whether the results corresponded to the true sex of the bone or not, the average of the two indices obtained from each bone has been recorded.

The average values of the width and of the depth of the sciatic notches of each foetus, and an average of the sciatic notch indices obtained, were recorded. No separate analysis of right and left has been attempted.

Values for the sciatic notch index in British material were taken from the 33 foetuses investigated by Boucher ('55) and

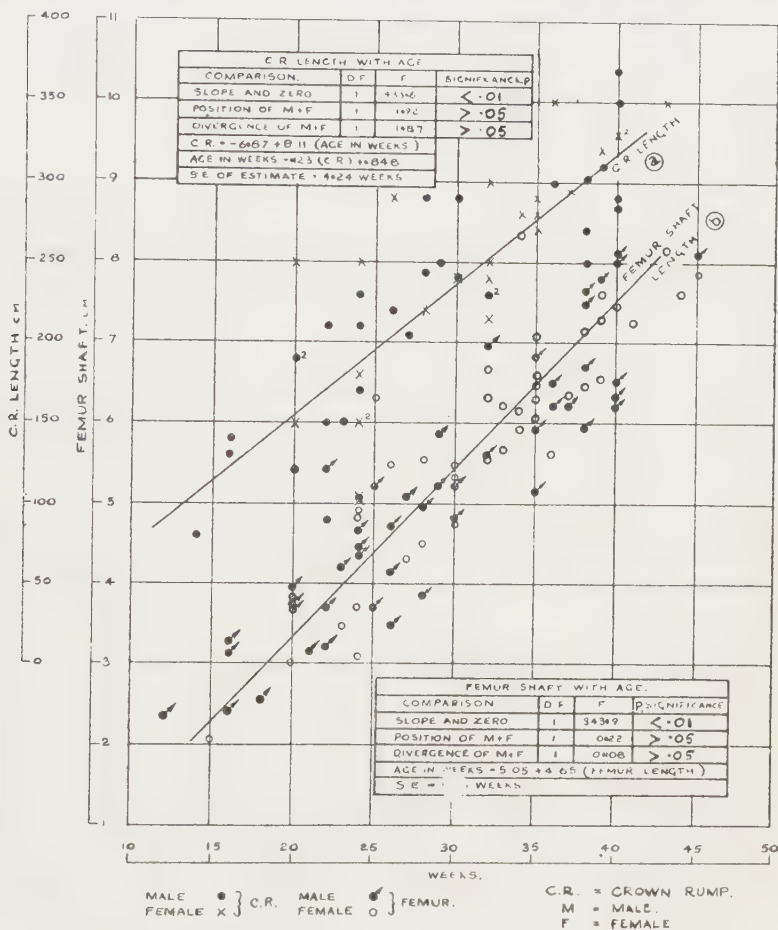


Fig. 3 A significant difference in the comparisons made between the slope of the combined male and female Crown-Rump (Graph a), and femur shaft (Graph b) lengths with age, and the horizontal is shown. ( $p < .01$ ). The other comparisons made are not significant.

from an additional 74 foetal bones of known sex and race lent by Sir Sydney Smith.<sup>2</sup>

#### RESULTS

The measurements made on each foetus of the crown rump length, the length of the shaft of the femur and of the subpubic angle, and the ischium and pubis lengths, and the ischium and pubis indices; both in unfixed cartilage and in bone, and the width, depth and index of the sciatic notch, are recorded for all subjects in table 1.

In order to construct a base line for age to which other variables may be related, a study was made of the relationship of crown rump length to the gestation age recorded in weeks (fig. 3). No significant difference was found between the slope for females and that for males, so the combined figures were used to obtain the regression line "a" in fig. 3.

The average amount of change of total femur length, after fixation, was  $-.07$  cm. There was no change in 16 foetuses, in 11 there was shrinkage, and in 36 an increase in length. Small changes were found in the ischium pubis index obtained after fixation, from that taken before fixation, and in view of the changes found in the femur, it was decided to report only the latter values.

The averages of the lengths of the right and left femoral diaphysis of the Negroes are shown plotted against age in fig. 3. (The age was derived from the C.R. length via "a," fig. 3, when no gestation age was given in the records.) No significant deviation of the slope for males from that for females was found, and the combined values were used to obtain the regression line "b."

The analyses by the *t* test of the differences of value of the ischium pubis index in cartilage and bone, of the subpubic angle and of the sciatic notch index, between the sexes, are

<sup>2</sup> The writer is very grateful to Sir Sydney Smith for making these bones available for measurement.

recorded in table 2. There is no significant sex difference between the ischium pubis indices of either the bony or cartilaginous pelvis.

The subpubic angle is significantly larger in the Negro female than in the male, and the sex difference is also significant in the group of American Whites. The differences between American Negro and American White males, and between American Negro and American White females, are not significant.

TABLE 2

*Comparison of data from different racial and sexual groups*

ISCHIUM PUBIS INDEX U.S.A.				SUBPUBIC ANGLE		SCIATIC NOTCH INDEX						
Cartilage.		Bone.		U.S.A.		U.S.A.		Gt Britain.				
	NM.	NF.	WM.	W.F.	NM.	NF.	WM.	W.F.	NM.	NF.	WM.	W.F.
	T.	.93	1.3	2.43	.152	.118	4.31	4.64	67.66	0	2544	94
	n.	49	45		70	44	39	34	95	67		94
	p.	>.5	>.5		>.5	>.5	<.01	>.5	<.01	>.5	<.01	<.01
	T.		1.148		1.06		.029		.726		1866	
	NF.	n.	42		42		28		59		106	
	p.		>.25		>.5		>.5		>.4		>.05	
	T.		.048		.887		4.75	0	12.17		8.161	
	WM.	n.	23		22		23		31		105	
	p.		>.5		>.3		<.01		>.2		<.01	

Showing values of *t*, the degrees of freedom *n*., and the probabilities of the results having occurred by chance, *p*, where values of  $<.01$  are significant.

Significant differences between the subpubic angles of both American White and American Negro males and females, and between the sciatic notch indices of males and females, both American Negro and American White, and also between the sciatic notch indices of British White males and American Negro males are shown, with absence of significant differences in any of the other comparisons made.

The values for the sciatic notch index range from 3.38 to 8.77. To obtain the best separation in the British White group, the value 5 was considered to be female and 4.9 male, but in the Negro group, 5 had to be taken as the upper limit in males in order to get the best separation, with 5.1 the lowest female value. The sciatic notch index is significantly larger in females than in males, both British White and American Negro, while there is no sex difference in the American Whites

(divided in the same way as the British Whites). The British White males and the American Negro males are significantly different while the females of these groups are not.

The width and depth of the sciatic notch of the Negroes (each an average of four readings as described), are shown plotted against age in fig. 4. The divergence of the slopes for width, and the difference in position of these lines, between males and females, is significant. The difference in position

TABLE 3  
*Tests of correlation in Negro material*

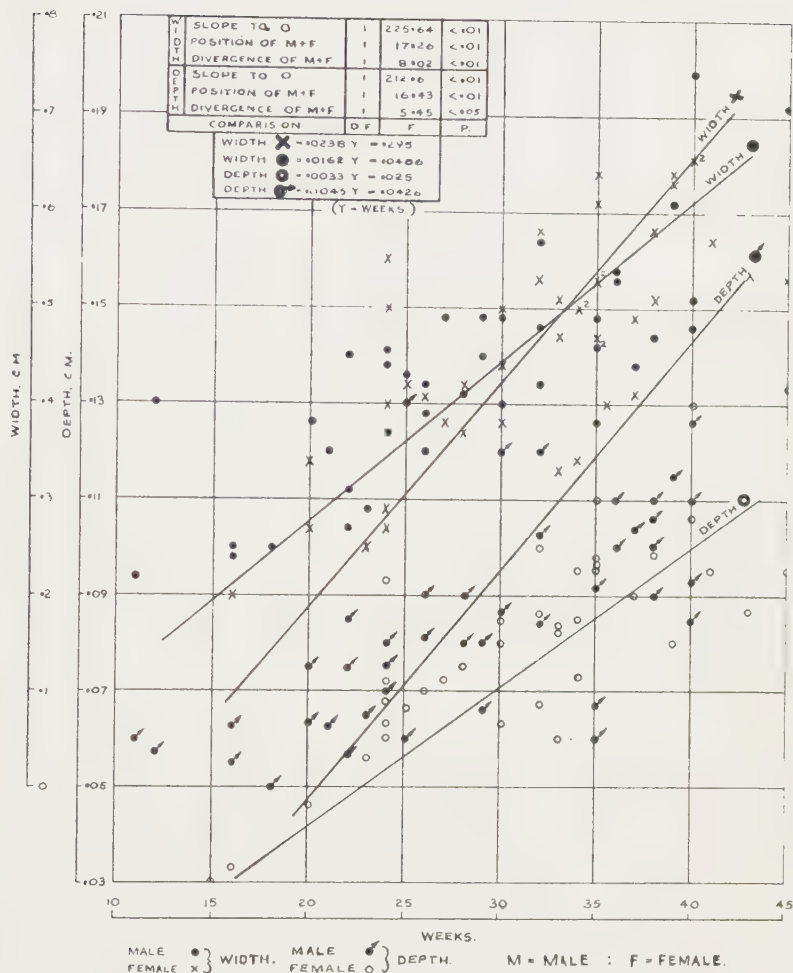
	I.P. INDEX	CART.	S. NOTCH INDEX.	
	M.	F.	M.	F.
I.P. Index Bone.	$r = .2493$ $t = .45$ (S.E. = $\pm .1757$ ) N = 28	$r = .0785$ $t = 1.5$ (S.E. = $\pm .1612$ ) N = 33		
Sub pubic Angle	$r = .0066$ $t = .04$ (S.E. = $\pm .169$ ) N = 35	$r = .2241$ $t = 1.4$ (S.E. = $\pm .1605$ ) N = 34	$r = .027$ $t = .16$ (S.E. = $\pm .169$ ) N = 35	$r = .341$ $t = 2.3$ (S.E. = $\pm .1494$ ) N = 34
	SCIATIC NOTCH		Width	
	M.	F.		
S. Notch Depth.	$r = .809$ $t = 15.9$ (S.E. = $\pm .0509$ ) N = 47	$r = .882$ $t = 26.7$ (S.E. = $\pm .03315$ ) N = 47		

Showing correlation coefficients  $r$ , S.E., the Standard Error of  $r$ . Values of  $t$  greater than 3 are significant for the size of the samples studied. The correlation of the width with the depth of the sciatic notch is significant in both males and females. The other correlations made are not significant.

of the slopes for depth is significant between male and female, whilst their divergence is of borderline significance.

Coefficients of correlation are shown in table 3. The values obtained for the cartilaginous with the bony ischium pubis indices, and the cartilaginous I.P. index with the subpubic angle were not high. Similarly, the correlation of the sciatic notch index with the subpubic angle is not high, but it may be noted to be higher in females than in males. Correlation between the width and depth of the sciatic notch is highly significant in Negro males and females, in spite of the different





NEGRO FOETUSES :— DEPTH AND WIDTH OF SCIATIC NOTCH WITH AGE.

Fig. 4 Significant differences in the comparisons made between the slopes of the combined male and female figures for both width and depth of the Sciatic Notch with age, and the horizontal are shown, ( $p .01$ ). Significant differences between the position of the slopes for width and depth, and the divergence of the slopes for width of the Sciatic Notch with age, between males and females are shown, ( $p .01$ ). The divergence of the slopes for the depth of the sciatic notch with age between males and females shows borderline significance. ( $p .05$ ).

slopes of the regression lines for width and depth described above.

The figures for bony ischium pubis indices do not show sex differences when the results are grouped according to the types of pubic ossification described by Caffey and Madell ('56), where A equals a single rod of bone in the superior

TABLE 4

*Ischium pubis index grouped according to pubic type*

A		B		C		Type.
M	F	M	F	M	F	Sex.
3	6	12	12	18	19	Number.
43%	40.92%	68.96%	67.83%	79.58%	84.1%	Index (Mean.)
t = .256		t = .262		t = 1.766		t
> .5		> .5		> .2		P of results occurring by chance.

Comparison of the ischium-pubis index in males and females, grouped according to the type of pubic ossification. (Caffey and Madell 1956). (A = single rod in superior ramus. B = dumb-bell centre in superior ramus. C = hook shaped centre extending into the inferior ramus.) T tests show no significant sex differences in any of these groups.

TABLE 5

*Growth of the ischium and pubis in the American Negro*  
*Comparison of male and female data*

	COMPARISON.	D. F.	F.	SIGNIFICANCE. p
ISCHIUM BONE.	Slope to O. 1	1	268.82	< .01 +
	Position M to F. 2	1	.56	> .05
	Difference M and F. 3	1	1.3	> .05
I. CARTILAGE.	1	1	218.97	< .01 +
	2	1	.569	> .05
	3	1	1.26	> .05
PUBIS BONE.	1	1	73.46	< .01 +
	2	1	.19	> .05
	3	1	.52	> .05
P. CARTILAGE.	1	1	139.83	< .01 +
	2	1	.42	> .05
	3	1	.957	> .05

Comparison of the rates of growth and sizes of the ischium and pubis (in both cartilage and bone) with age between American Negro males and females. Showing no significant differences in either the sizes or the rates of growth of these bones, between males and females.

ramus, B equals a dumb-bell centre, and C equals a hooked centre, where ossification has extended into the inferior ramus. See table 4.

The relationship of the lengths of the ischium and pubis to age (bony or cartilaginous) shows no significant sex differences. See table 5.

#### DISCUSSION

It was impossible to study all the variables without having a way to estimate the gestation age from the C.R. length in cases in which this information was lacking. It was not desirable to use figures for mixed or all white populations in the study of negro material, so that in the absence of tables relating crown rump length to gestation age in Negro foetuses, the gestation age given on the records was assumed to be accurate. The S.E. for the estimation of age from the C.R. length was four weeks. The S.E. for the estimation of age from the femur length is smaller ( $1\frac{1}{4}$  weeks) probably because in 41 out of 96 cases the age was taken from the C.R. length via fig. 3, graph a. The absence of sex differences in the growth of this diaphysis and of the C.R. length suggests that the overall growth and actual dimensions of the foetus are not different in the two sexes. This made it possible to anticipate that any differences found in the dimensions or rates of growth of any other parts would be specifically due to their sex.

The effects of refrigeration on the dimensions of the foetus are not known to the writer. No visibly distorted material was used, measurements were made on thawed material, and the sexes were evenly distributed among the material frozen for different lengths of time, so that any inaccuracies due to this type of preservation would have affected the sexes equally. Measurements from the fixed material were not used because the slight changes found after fixation might have added to any inaccuracies already present.

It was noted, in defining the point A, that the foetal acetabulum has a uniform pattern. The trefoil appearance, already described, takes many forms. The lobes have varying propor-

tions but the middle lobe is always the best defined and the largest. The point A that has been defined above is comparable to the point A of Schultz ('30) which was defined on immature material. It is possible that the notch in the edge of the articular surface that Washburn ('48) notes in describing the location of a similar point in adult material, " (3) Often there is a notch in the border of the articular surface in the acetabulum," might be shown to be equivalent to the central lobe, by further investigation of material from children.

Washburn (1948) has followed up the work done by Schultz ('30) on the ischium pubis index, and has shown significant differences between the indices obtained from male and female pelvis, in both White and Negro adult material. X-Ray studies of the infant pelvis by Reynolds ('45) showed sex differences of borderline significance. Washburn therefore postulated that the growth rate of the pubis is greater at puberty in the female than in the male. He also suggested dependency of the sex difference of the sub-pubic angle on this growth. He writes, in relation to the work on infant material mentioned above, "... since Reynolds measured the bone length on Roentgenograms there may well be a difference in technique, and it is quite possible that small growth changes in the ischium pubis index might appear if one technique could be followed throughout."

There is no evidence from this Negro material to suggest that the pubis is larger, or grows faster, in the female than in the male. As the methods used in this study include that applied by Washburn to adult material, these results can be compared with the work quoted in the above paragraph, and they do uphold the contention that there is no sex difference in the foetal pubis. A significant sex difference exists, however, in the subpubic angle. The difference between the means in the American Negro foetus is  $15.5^\circ$  in this material. Verneau (1875) gives figures for the means of American Negro adults with a separation of  $10.6^\circ$ . Exact comparison cannot be made as Verneau gives means and not individual values. The situation in the smaller group of American White foetuses is simi-

lar; the difference is  $22.95^\circ$  and is statistically significant. Verneau gives a mean value for 35 adult European White females, which is  $14^\circ$  higher than that obtained from 63 men. Thomson (1899) gives figures with a difference of means of  $18^\circ$  in foetal British Whites. The difference is again larger in the foetal pelvis which are, however, few in number. The mean value in all these groups is larger in the female (and the means are larger in the foetal groups, male and female, than in the adult groups). It is unfortunate that statistical analysis cannot be made owing to the absence of individual readings in the older works, and to the absence of information as to how these measurements were made.

There would seem to be a greater sex difference in the subpubic angles of the foetus than of the adult, which would suggest that increased growth of the pubis in females in puberty is not responsible for the sex differences in the subpubic angle.

The measurements of the sciatic notch index confirm the observations of Verneau (1875) and Thomson (1899) that there is a sex difference in the foetal notch (also Fehling 1876). This is statistically significant in the American Negro and British White but not in the American White. This last fact is difficult to explain as the specimens were measured at random in an identical manner by the same person, with no knowledge of the sex or race of the bone in hand. The subpubic angle is significantly larger in the American White females so that it is unlikely that the material was, for some reason, grossly abnormal. Bad separation could have been explained as due to "racial mixture" had the "wrong" values all been close to the borderline values. Out of 19 males, 8 have an index in the female range (5.1 to 6.0). In the females, 4 out of 14 are in the male range, all at 4.9, and it seems, therefore, that there is something unusual in these American Whites for which, at present, no explanation can be offered.

In Britain, the sciatic notch index can be used in mediocolegal work with a known degree of accuracy, but as it cannot be assumed that the American material studied was ex-



ceptional and that British figures are applicable, further work would be necessary on American Whites before this index could be of use in the U. S. A., in material of unknown race.

Verneau (1875) commented on the greater depth, in both children and adults, of the sciatic notch in males, while Villemin ('37), stated that there was no difference in the depth of the notch in children of up to 20 years, but that the width became increasingly greater in girls than in boys. Lazorthes and Lhez ('38, '39) describe a greater width of the notch in females than in males, both in children and in adults, and state that the depth does not differ.

Letterman ('41) found significant sex differences in both width and depth of the sciatic notch in adult American pelvises, the width of the notch being significantly greater and the depth significantly less in both male and female Negroes than in the corresponding White groups.

The study of the growth of width and depth of the bony sciatic notch in the American Negro fetuses, shows that the growth rate of the width, is greater in the female than in the male throughout the period of gestation studied.  $P = <.01$  for the divergence, and  $P = <.01$  for the position of the regression lines for width having occurred by chance). The depth, and the growth rate of the depth, are greater in males over the same period. ( $p <.05$  for the divergence, and  $p <.01$  for the position of the regression lines as above.) The absence of sex differences in the growth of the crown rump length, femur shaft length, and the lengths of the ischium and pubis is evidence that these differences in width and depth of the sciatic notch are sex differences. This agrees with the first part of Letterman's observations mentioned above.

Letterman's observations of increased width and decreased depth of the sciatic notch in Negroes as compared with Whites, has not been confirmed by the results obtained from this foetal material, even although the separating value between the sexes is higher in the Negro group. This is because the data on the British White material do not include enough exact ages (or femur lengths), for analysis of width and depth of

the notch with age to be made. It is not possible to say, therefore, whether the significantly higher values of the sciatic notch index in the Negro male, as compared with the White male, is due to differences in the width, the depth, or to both of these measurements of the sciatic notch.

The more closely correlated the width is with the depth of the sciatic notch, the more likely it is that the notch is growing uniformly. Thus there is less change in the proportions of the female notch in the period studied in the Negro material ( $r = .882 = 26$  S.E.), than there is in the male notch ( $r = .809 = 15.9$  S.E.). The role of the growth in width of the notch in females is probably less important in sex differentiation therefore, than that of the decreased rate of growth in width of the male notch. The decreased rate of growth of the width of the male notch is more important a factor than any increase in the depth of the notch in males, because the regression lines for depth show only borderline sex differences, while those for width, show a divergence between the sexes that is highly significant.

The correlation of the sciatic notch index with the subpubic angle in the Negro, was low, as had been found in an X-ray study in the adult by Young and Ince ('40). It has been said that this low correlation is due to the developmental dependence of these features on different factors, acting at different times, "... the excess of growth which characterizes these parts of the female pelvis"—referring to the pubis—"at puberty has a hormonal basis" (Greulich and Thoms ('44), while Washburn ('48) says "Statistics, growth and comparative anatomy all show that the sex difference in the sciatic notch belongs to a different system to that in the pubic bone." It seems from the present evidence that sex differences appear in the subpubic angle as early in gestation as do those of the sciatic notch and, so far there is no evidence that these sex differences are increased in the adult (see page 595), so that the lack of correlation loses some of its original meaning and still requires interpretation.

This low correlation could be due to the use of unsatisfactory methods for the expression of physiological processes, or to the development of these features at different rates. There is no evidence that either measurement is changing with age however, during gestation, and without further data it is impossible to attempt an explanation of this finding.

The development of male characteristics in the male foetus is thought to be due to factors produced in the gonadal tissue (Jost '50). In following up the suggestion made that the sex differences in the sciatic notch are predominantly dependent on male growth changes (as far as can be gauged from the period of gestation studied), it would be helpful, in the absence of any experimental animal, to study material from hormonally abnormal fetuses (using the method of Moore and Barr '54) to confirm the genetic sex from the nuclei, if such material could be obtained.

#### SUMMARY

1. Sex differences in the foetal pelvis have been investigated in 96 American Negro and 33 American White fetuses. The bony sciatic notch has been studied in an additional 107 British White fetuses.

2. No sex differences in the increase of either the crown rump length, or the femur shaft length with age have been found.

3. A point "A," in the acetabulum has been defined, from which ischium and pubis lengths can be measured in the cartilaginous pelvis.

4. No sex differences have been found in the growth of the ischium or pubis with age, or of the ischium pubis indices, either of the bony or cartilaginous pelvises.

5. Significant sex differences have been found in the subpubic angles of American Negro and American White fetuses. These have been compared to adult figures, and the effect on the subpubic angle of the increased growth of the pubis in females at puberty has been discussed.

6. Both width and depth of the sciatic notch and the increase of these dimensions with age were found to have significant sex differences, and the suggestion was made that the decreased rate of increase in the width of the male notch, as compared to the female, was a specific male characteristic.

7. The sciatic notch index was found to be significantly higher in females than in males, of both American Negro and British White foetuses. No sex difference was found in the American White. The effects of the different separating values found in these two races, on the use of this index in forensic work has been discussed, and the need for further study of white material has been emphasized.

#### ACKNOWLEDGMENTS

Grateful thanks are expressed to Professor Mildred Trotter and to Professor R. J. Harrison for their unfailing interest and encouragement, to the anatomy departments involved for the facilities so cheerfully provided, to Barbara Bartels Hixon for advice on statistical methods, to Mrs. I. M. Marlow for most patient work on the typescript, and also to the Academic Board of the London Hospital Medical College and to Dr. P. L. Boucher for making this work possible by their moral and financial support.

#### LITERATURE CITED

- BOUCHER, B. J. 1955 Sex difference in the foetal sciatic notch. *J. For. Med.*, 2: 51-54.
- CAFFEY, J., AND S. H. MADELL 1956 Ossification of the pubic bones at birth. *Radiology*, 67: 346-350.
- FEHLING, H. 1876 Die form des becken beim fötus und neugeborenen und ihre beziehung zu der beim erwachsenen. *Arch. Für Gyn.*, Band, 10: 1-80.
- GREULICH, W. W., AND H. THOMS 1944 The growth and development of individual girls before, during and after puberty. *Yale J. Biol. and Med.*, 17: 91-97.
- JOST, A. 1950 Recherches sur le contrôle hormonal de l'organogenèse sexuelle du lapin et remarques sur certaines malformations de l'appareil génital humain. *Gyn. et Obst.*, 49: 44-60.
- LAZORTHES, G., AND A. LHEZ 1939 La grande échanerure sciatique; étude de sa morphologie et de ses caractères sexuels. *Arch. d'anat. et d'hist. et d'emb.*, 27: 143-169.

- LETTERMAN, G. S. 1941 Greater sciatic notch in American whites and Negroes. *Am. J. Phys. Anthropol.*, 28: 99-116.
- MOORE, K. L., AND M. L. BARR 1954 Nuclear morphology, according to sex in human tissues. *Acta Anat.*, 21: 197-205.
- REYNOLDS, E. L. 1945 The bony pelvic girdle in early infancy; roentgenometric study. *Am. J. Phys. Anthropol.*, 3: 321-354.
- SCHULTZ, A. H. 1930 Skeleton of trunk and limbs of higher primates. *Human Biology*, 2: 303-409.
- THOMSON, A. 1899 Sexual differences of the foetal pelvis. *J. Anat.*, 33: 359-380.
- VERNEAU, R. 1875 *Le Bassin dans les Sexes et dans les Races*. Paris.
- VILLEMIN, F. 1937 La différenciation sexuelle précoce de la grande échancrure sciatique, et son retentissement sur l'évolution du bassin chez les hommes. *Strasbourg Med.*, 33: 593-625.
- WASHBURN, S. L. 1948 Sex differences in the pubic bone. *Am. J. Phys. Anthropol.*, n.s. 6: 199-207.
- YOUNG, M., AND J. G. H. INCE 1940 Radiographic comparison of the male and female pelvis. *J. Anat.*, 74: 374-385.



# THE USE OF BONE WEIGHT FOR HUMAN IDENTIFICATION

PAUL T. BAKER<sup>1</sup> AND RUSSELL W. NEWMAN  
*QM Research and Engineering Center, Natick, Mass.*

FOUR FIGURES

## INTRODUCTION

Within the past few years physical anthropologists have become increasingly involved in the problems of human identification. Techniques have been applied to individuals which were originally devised for the description of groups, and while these are the best available, they do not provide the desired certainty for the identification of an individual. Recent work on identification criteria has concentrated on improving the existing methods. Trotter and Gleser ('52) have published new material on stature estimation, and Stewart and Trotter ('54) have put together all the important previous material on aging. Currently, research is underway to improve techniques for age estimation (McKern and Stewart, '57).

There is obviously a need not only for the improvement of older methods, but also for the establishment of new criteria.

A measurement of the living weight of a man is a potentially important piece of information available to the identification worker; however, present techniques have not permitted any statistical use of these data. Anthropologists have felt that the size and weight of the skeleton were a good guide to the living weight of the individual, but no quantification was attempted. Ingalls ('31) reported that bone weights fluctuated in the same direction as body weight with aging. However, he does not present individual data and draws his conclusions

<sup>1</sup>Present address: Pennsylvania State University, University Park, Pa.

from cross-sectional group fluctuations. More recently Trotter ('54) established that dry skeletal weight is related to living stature, but the correlation is not high enough to warrant stature prediction on a bone-weight basis. Physiologists have claimed that bone mineral constitutes 5 to 7% of the fat free weight of the body (Behnke et al., '42). In all cases it is implied that the skeletal weight forms a relatively constant proportion of the normal human body. If the bone does form a consistent segment, it could also act as a convenient guide for predicting the living weight. With this prediction in mind, research was undertaken by Army Graves Registration Service Headquarters, Kokura, Japan on the war dead remains that were being repatriated during "Operation Glory."

#### PREPARATION AND MEASUREMENTS

For the purposes of this study only remains which had been completely skeletonized by natural factors were used. Care was also taken to select only complete skeletons from which the fat in the bone had leached out; bones were not defatted by chemical or mechanical means. Moisture was removed from the skeleton by drying at a temperature of 150°F until there was less than a 10 gm per hour loss. This usually required 12 to 15 hours of drying. The complete skeleton and its segmental parts were weighed and measured before the bones had reabsorbed the atmospheric moisture at room temperature.

Measurements were made on 125 skeletons. Dry weight of the total skeleton, the skull, and the following right and left bones and bone combinations was obtained: femur, tibia plus fibula, humerus, radius plus ulna, innominate, and clavicle. Maximum lengths were taken of the long bones using an osteometric board. Volume measurements of the right clavicle and long bones were made by water displacement in specially constructed tanks. Two different containers were used. One tank 61 cm high and 10.0 by 12.6 cm in cross section was used for measuring femur and tibia plus fibula volume. The other

bones were measured in a cylinder 51 cm high and 9.4 cm in diameter. The meniscal change in an attached glass tube of 4 mm inside diameter was measured in millimeters and converted to cubic centimeters of water. These values were corrected for water absorption in the bone by weighing the bone before and after immersion. Measurement by other volumetric techniques was not attempted.

The identification of the individuals studied was not available to the investigators at the time of measurement, and the sample was not selected for any biological criteria other than condition and completeness. Individual's specimens on whom identification was not established by the Army Graves

TABLE 1  
*Demographic data on the skeletal population*

		AGE			LIVING WEIGHT		STATUEE	
		N	Mean	S.D.	Mean	S.D.	Mean	S.D.
			<i>yr.</i>			<i>lb.</i>		<i>in.</i>
Killed in action	Whites	15	20.3	1.3	140.3	16.4	68.2	2.0
	Negroes	1	18.2	—	176.0	—	67.2	—
Died as POWS	Whites	80	25.4	6.0	152.7	26.3	68.2	2.6
	Negroes	19	26.5	3.4	145.5	14.9	67.9	2.6

Registration Services were rejected from the series before statistical analysis. The demographic information presented in table 1 was obtained from personnel files at the Office of the Quartermaster General.

## RESULTS

### *Nutritional and racial factors in bone weight*

The skeletal material used in the study came from many different cemeteries in North Korea, and it is possible that differing soil conditions could lead to differential leaching and decaying processes. The internal consistency of the sample was investigated, but only one significant factor was uncovered: the soldiers killed in action and interred by Americans were wrapped in canvas, while those who died in POW

camps were buried without any cover. Consequently, the skeletons of the men killed in action still contained appreciable fat and could not be used for this analysis without defatting.

The exclusive use of the remains of men who died in POW camps made it necessary to consider the possible effects of nutritional deficiency on bone weight. Two methods were used to investigate this problem. First, the skeletal weight

TABLE 2  
*Negro-White differences in bone measurements*

	WHITE		NEGRO		NEGRO-WHITE	"t"
	Mean	S.D.	Mean	S.D.	Mean difference	
	gm		gm		gm	
Dry weight						
Total skeleton	4290	607	4585	445	295	2.41 <sup>1</sup>
Rt. femur	409	60	420	41	11	.94
Rt. tibia + fibula	299	50	324	36	25	2.38 <sup>1</sup>
Rt. humerus	152	23	166	22	14	2.33 <sup>1</sup>
Rt. radius + ulna	106	16	121	13	15	4.35 <sup>2</sup>
Rt. clavicle	22	5	23	4	1	.76
Rt. innominate	184	34	180	28	— 4	— .53
Skull	676	117	740	77	64	2.90 <sup>2</sup>
Volume						
Rt. femur	398	88	410	77	12	.58
Length						
Rt. femur	470	24	476	23	6	1.00
Sample size	80		19			

<sup>1</sup> 5% level of significance = 1.99.

<sup>2</sup> 1% level of significance = 2.63.

of men who were reported to have died from nutritional deficiency diseases was compared to the skeletal weight of those who presumably died from pulmonary disorders. Second, skeletal weights were correlated to the length of time that a man was held prisoner prior to his death. In neither case were the results statistically significant. This is partially explained by the short time the men spent as prisoners of war; the average was only four and one-half months with a

standard deviation of less than two months. While these tests cannot be considered conclusive evidence concerning the effects of nutritional inadequacy on adult bone weight, for the purposes of this study, the men who died from deficiency diseases did not show significant changes in bone weight.

Within the POW war dead group significant racial differences appeared in the bone weights. The Negro skeletons were approximately 7% heavier than the White skeletons, even though the living weight of the Negroes at the time of induction into the Army was 5% (or 7 pounds) lighter than the Whites. An analysis of the differences in individual bones, given in table 2 shows that the difference is concentrated in the extremities and the skull. In contrast, the innominate bone is slightly heavier in the Whites.

The overall skeletal difference in weight as well as the segmental difference required separate racial analyses.

*The relationship between living weight  
and bone measurements*

The plots of living weights against total skeletal weights are shown in figures 1 and 2. Although the relationship is closer for the Whites, it can be seen from the figures that the correspondence between these two weights is not high for either Whites or Negroes. The correlation coefficient for the Whites is .544 and for the Negroes .392. In neither case are the values sufficient to make dry skeletal weight an efficient predictor for exact living weight. However, the correspondence found for Whites is close enough to warrant broad classification, that is, a low bone weight may be safely ascribed to an individual of below average weight, and an average skeletal weight belongs to a person who was of near average weight. The top of the scale presents a more complex picture because a very heavy person may have only a moderately heavy skeleton. It appears that whatever relationship exists between total weight and skeletal weight is a function of the correspondence between the bone and the rest of the fat free tissue. Therefore, very obese individuals have the same



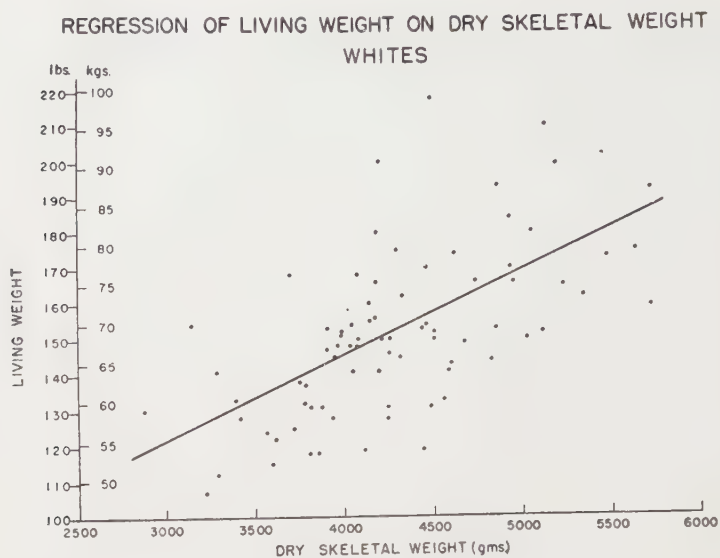


Figure 1

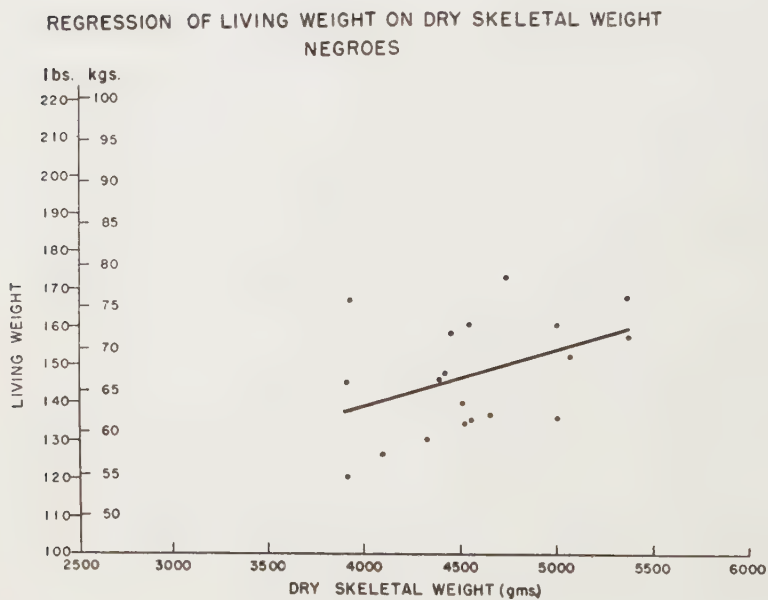


Figure 2

bone weights that would be found for men who weighed as much as a hundred pounds less.

In an effort to simplify the procedures and eliminate the requirement that the total skeleton be present, the relationship between femur measurements (the heaviest single bone in the body) and living weight was investigated. The correlation coefficients are presented in table 3, and the plots are shown in figures 3 and 4.

TABLE 3  
*The correlation coefficients of bone measurements to living weight*

	WHITES	NEGROES
	r	r
Living weight to dry skeletal weight	.544 <sup>2</sup>	.392
Living weight to dry femur weight	.535 <sup>2</sup>	.449 <sup>1</sup>
Living weight to femur volume	.398 <sup>2</sup>	.042
Living weight to femur length	.295 <sup>2</sup>	.085

<sup>1</sup> 5% level of significance = .456.

<sup>2</sup> Significant at the 1% level.

The correlation coefficients of dry femur weight to living weight for the Whites and Negroes are equivalent to those obtained by using the total skeleton, and the use of the femur alone seems well warranted as measurement of the femur alone is simpler than total skeletal weight and can be used even on incomplete skeletons. In the White sample the additional femur measurements of volume and length were also significantly correlated to living weight, but a multiple correlation using all three femur measurements was only .541, which is not substantially better than the value using only femur weight, and requires additional measures. It appears that dry femur weight alone is probably the most efficient predictor available. Table 4 gives the prediction equations which can be used for the prediction of living weight. Separate equations must be used for Negroes and Whites to insure maximum accuracy of prediction.

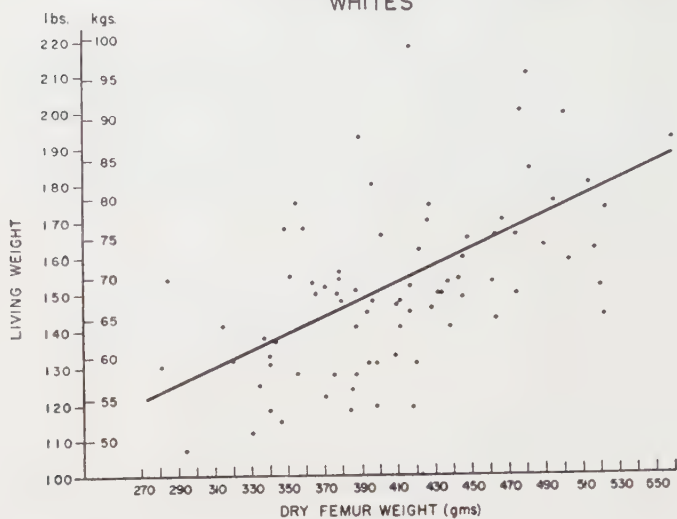
REGRESSION OF LIVING WEIGHT ON DRY FEMUR WEIGHT  
WHITES

Figure 3

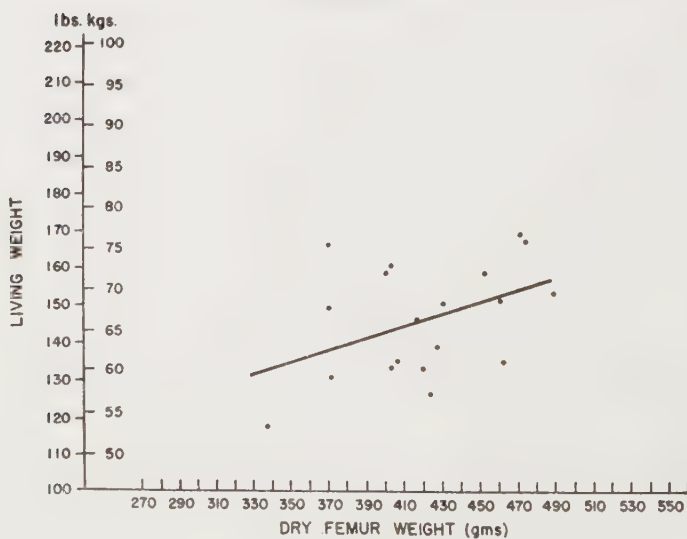
REGRESSION OF LIVING WEIGHT ON DRY FEMUR WEIGHT  
NEGROES

Figure 4

*The prediction of bone weights from  
living weight and stature*

In the preceding section the analysis has been directed toward predicting living weight from the skeletal material. A different, but equally valid, approach for associating an unknown skeleton with a specific individual is the prediction of a skeletal characteristic from information concerning the individual while alive. In this case bone weights may be

TABLE 4  
*Equations for the prediction of living weights from bone weights*

Whites	Living weight <sup>1</sup> = .024 (Dry skeletal weight) <sup>1</sup> + 50.593 ± 20.1
	Living weight = .233 (Dry femur weight) + 57.385 ± 22.2
Negroes	Living weight = .013 (Dry skeletal weight) + 85.406 ± 13.7
	Living weight = .163 (Dry femur weight) + 76.962 ± 13.3

<sup>1</sup> Living weight in pounds. Bone weight in grams.

TABLE 5  
*The multiple correlation coefficients and regression equations  
of stature and weight to dry skeletal weight*

	R	REGRESSION
White	.642	Dry skeletal weight <sup>1</sup> = 8.155 living weight <sup>1</sup> + 91.736 stature <sup>1</sup> — 3214.457 ± 462
Negro	.541	Dry skeletal weight = 5.545 living weight + 74.374 stature — 1273.608 ± 376

<sup>1</sup> Dry bone weight in grams. Living weight in pounds. Stature in inches.

predicted from the living stature and weight. The multiple correlation coefficients and regression equations for total skeletal weight from stature and living weight are shown in table 5.

These correlation coefficients are substantially better than those obtained by using the reverse procedure of predicting living weight from bone measurements. As shown by the R values, the application of the same weight and stature criteria gives an even better prediction of femur weight than skeletal

weight. The exact reasons for this further improvement are not obvious, but it may be that the lesser degree of weathering and other post mortem changes in the femur make its weight a more accurate measurement than total skeletal weight. Whatever the reason may be the higher correlations indicate that the femur weight should be used and the more difficult measurement of skeletal weight is not required for implementing this identification technique. Table 6 gives the multiple correlation coefficient values and the regression equations derived from these samples.

TABLE 6

*The multiple correlation coefficients and regression equations of stature and weight to dry femur weight*

	R	REGRESSION
White	.703	Right femur weight <sup>1</sup> = .650 living weight <sup>1</sup> + 12.314 stature <sup>1</sup> — 530.073 ± 43.1
Negro	.706	Right femur weight = .405 living weight + 10.001 stature — 317.912 ± 29.2

<sup>1</sup> Femur weight in grams. Living weight in pounds. Stature in inches.

### *The interrelationship of the skeletal components*

When commingled remains are found they must be separated into skeletons representing the individuals present in the common grave. With present techniques the anthropologist must depend on the subjective criteria of morphology, color, and component articulation. The dry bone weight offers an additional and objective criterion for segregating the bones into individuals. Table 7 gives the correlation matrices for the skeletal parts, and the prediction formulae for all significant relationships are given in Appendix B. The intercorrelations of the skeletal components are high enough to warrant accurate prediction in many cases. When the correlation is above .8 the actual weight of bone Y should correspond closely with the value predicted from bone X. When the "r" value falls between .7 and .8 a greater differ-



ence should be expected. Below a coefficient of .7 large discrepancies may be anticipated.

From the matrices it is apparent that the skull weight is very poorly related to the axial skeletal components and the weights do not offer a practical method for establishing association.

TABLE 7  
*The intercorrelations of dry bone weights*

WHITES N = 80	RIGHT FEMUR	RIGHT (TIBIA AND FIBULA)	RIGHT HUM- ERUS	RIGHT (RADIUS AND ULNA)	RIGHT CLAVICLE	RIGHT INNO- M- INATE	SKULL
Total skeletal	.887	.878	.842	.841	.720	.917	.724
Right femur		.906	.739	.771	.601	.829	.464
Right (tibia and fibula)			.762	.793	.602	.767	.480
Right humerus				.851	.659	.777	.459
Right (radius and ulna)					.715	.754	.482
Right clavicle						.634	.508
Right innominate							.549
5% level of significance = .220			1% level of significance = .287				
NEGROES N = 19	RIGHT FEMUR	RIGHT (TIBIA AND FIBULA)	RIGHT HUM- ERUS	RIGHT (RADIUS AND ULNA)	RIGHT CLAVICLE	RIGHT INNO- M- INATE	SKULL
Total skeletal	.828	.749	.606	.497	.507	.790	.397
Right femur		.862	.743	.636	.351	.760	.096
Right (tibia and fibula)			.701	.693	.373	.630	.160
Right humerus				.750	.235	.651	.138
Right (radius and ulna)					.556	.432	.079
Right clavicle						.262	.364
Right innominate							.371
5% level of significance = .456			1% level of significance = .575				

Bone weight intercorrelations are substantially lower for the Negroes. An examination of the methodology and statistical techniques failed to show any reason for this artifact and it must, therefore, be assumed that there is generally less interrelationship between the components of the Negro skeleton than there is in the White skeleton. Nevertheless, the long bone weights can be predicted with some accuracy even for the Negroes.

An additional independent criterion improves the association by reducing the probability of two individual bones having the same values. The femur analysis showed the length to be moderately independent of the weight. As indicated in table 8 the same is true of the other long bones.

Trotter and Gleser ('52) have shown that the long bone lengths are very highly intercorrelated and, since the lengths are moderately independent of the weights, length predictions can be added to weight predictions for a more accurate estimate of association. Trotter's article lists only the prediction equations for long bones from femur length. Thus, at present, length criteria can be applied only when the femur is present and in good condition. A practical example of how to use these criteria is given in Appendix A.

TABLE 8  
*Correlation coefficients of bone weights to bone lengths*

	FEMUR WT. TO FEMUR LGTH. r	TIBIA + FIBULA WT. TO TIBIA LGTH. r	HUMERUS WT. TO HUMERUS LGTH. r	RADIUS + ULNA WT. TO ULNA LGTH. r
Whites N = 71	.427	.553	.340	.600
Negroes N = 19	.504	.647	.457	.816

#### DISCUSSION AND CONCLUSIONS

The measurement of dry bone weight provides the identification specialist with new information which can be applied to two areas of identification. First, the bones may be associated with an individual by the prediction of dry femur weight from living stature and weight. Second, dry bone weights can be utilized for sorting individuals from commingled remains. However, drying the skeleton for weighing is a lengthy process which requires the use of large drying ovens and requires that the remains be skeletonized when obtained. Because many remains are not skeletonized when brought to the specialist, the prediction of dry femur weight from living stature and body weight cannot be used as a routine identification technique. Commingled remains are

generally skeletonized, and the technique of associating bones by weights can be implemented. The high degree of reliability inherent in the method makes it even more desirable as a standard procedure. Therefore, while the associations of femur weight with living weight and stature cannot at present be recommended as a standard tool, the segregating of commingled remains by bone weight could be used as a routine technique.

Stature reconstruction and age estimation from skeletal material has provided much interesting information about ancient populations. Unfortunately, the reconstruction of living weights from the skeletal weights of these populations does not appear to be a feasible undertaking. Cook and Heizer ('51 and '52) have shown that both the mineral and organic components of bone undergo radical change when buried in the soil for any great period of time. Therefore, while bone weights probably do not alter to any important extent in 5 or 10 years of burial (as is frequently encountered in forensic medico-legal identification work), they do alter after the many centuries involved in most archaeological specimens. Cook also found these changes to be highly individualistic to the site, making it impossible to even reconstruct the weight of the freshly de-fatted bone according to age. Unless the worker has the material and the patience to investigate the rate and nature of bone change for each given site, bone weights appear to have little utility in archaeological studies.

Throughout this report the standard errors of estimate of regression equations have been included for the guidance of the investigator in deciding how far individually calculated values may diverge from the expected results. However, the standard errors apply only to the samples reported here, so this statistic has two limitations which must be taken into account. First, any future sample will probably differ in some characteristics from the present one, and second, even if future samples were drawn from the same population, such samples will probably not have the same standard errors (Snedecor, '46). For these reasons the investigator should

use the standard error of the regression only as a general guide to divergence and not expect all his results to fall within the exact limits defined in this study.

#### SUMMARY

The skeletal remains of 125 individuals were dried and weighed to investigate the utility of bone weight for identification and for segregating individuals in group burials. Skeletal components formed differing proportions of total skeletal weight in Whites and Negroes: therefore, the racial groups were analyzed separately. It was found that broad categories of living weight can be predicted from total dry skeletal weight or from the dry right femur weight. However, the reliability of associating bone weights with living measurements can be increased by reversing the procedure, that is, predicting dry right femur weight from living weight and stature. The separate dry bone weights of the skeleton were found to be closely correlated to each other in most cases; in conjunction with length measurements they may be used for a highly reliable method of segregating commingled long bones into individuals. The regression equations and a practical example for segregating individuals are provided in the appendices.

#### ACKNOWLEDGMENTS

The authors wish to express their appreciation for the assistance and cooperation extended by the American Graves Registration Service personnel at Kokura, Japan in support of the collection of the data, and to the Memorial Division of the Office of The Quartermaster General for extracting and providing the required data from case histories. Finally, we would like to thank Miss Ella H. Munro for the statistical analysis of the material.

#### LITERATURE CITED

- BEHNKE, A. R., G. B. FEEN AND W. C. WELHAM 1942 The specific gravity of healthy men. *J. of Am. Med. Assoc.*, 118: 495-498.
- COOK, S. F. 1951 The fossilization of human bone: calcium, phosphate and carbonate. *Univ. of Calif. Pubs. in Am. Archaeol. and Ethnol.*, 40: no. 6.

- COOK, S. F., AND R. F. HEIZER 1952 The fossilization of bone: organic components and water. Univ. of Calif. Publs. in Am. Archaeol. and Ethno., 40: no. 8.
- INGALLS, N. W. 1931 Observations on bone weights. Am. J. Anat., 48: 45-98.
- McKERN, T. W., AND T. D. STEWART 1957 Skeletal age changes in young American males. Environmental Protection Research Division Technical Report No. 45, Quartermaster Research and Development Center, Natick, Mass.
- SNEDECOR, G. W. 1946 Statistical Methods. 4th Edition. The Iowa State College Press, Ames, Iowa.
- STEWART, T. D., AND M. TROTTER (Editors) 1954 Basic Readings on the Identification of Human Skeletons: Estimation of Age. Wenner-Gren Foundation for Anthropological Research Inc., New York, N.Y.
- TROTTER, M. 1954 A preliminary study of estimation of weight of the skeleton. Am. J. of Phys. Anthropol., n.s., 12: 537-552.
- TROTTER, M., AND G. C. GLESER 1952 Estimation of stature from long bones of American Whites and Negroes. Am. J. of Phys. Anthropol., n.s., 10: 463-514.

## APPENDIX A

*Theoretical examples for applying weight and length in determining bone association*

For this example it is assumed that the commingled fat-free bones of 6 White individuals have been found. All of the long bones should first be measured for length. Then they should be dried, as described in the Methods Section, and the individual bones weighed. Since the right femur weight is highly correlated to the other bone weights, it is a logical initial choice. The left femur will be easy to determine as it has an almost identical weight and length. From the right femur the weight of almost any bone belonging to the same individual can be predicted using the formulae presented in Appendix B. For example, if the femur weighed 409 gm, then the associated right humerus should weigh about 152 gm. It is not probable that any of the right humeri found will have exactly the predicted value, but one should fall within plus or minus 40 gm of this value. If more than one or none of the humeri are between these values, then using Trotter's regression equations, length measurement may be applied to determine the associated bone.

The same basic procedure applies to the association of the other long bones, although once two bones have been associated, both can be used for predicting the third. Thus, as each new bone is segregated new criteria are provided. This does not mean that the last associations need utilize all the other bones of the individual as predicting criteria;



such a process would be unwieldy and unnecessary. In general, the investigator should set up his own overall procedure, relying heavily on the prediction equations which are accompanied by high "r" values.

The use of bone weights and lengths in this manner will accurately segregate the major bones into individuals, but it does not solve the difficult problem of segregating the small bones such as ribs, vertebrae, and phalanges. However, the positive segregation of the major bones will provide the worker with a more accurate basis for applying subjective techniques to the rest of the skeleton.

*Prediction equations for estimating bone association*

Dry weight in grams. Equations based on the right side only of paired bones

## HUMAN BONE WEIGHTS

617

WHITE		NEGRO	
Total skeletal weight =		Total skeletal weight =	
8.841 Femur	+ 670.239 ± 278	8.988 Femur	+ 807.686 ± 251
10.823 (Tibia + Fibula)	+ 1036.579 ± 288	9.652 (Tibia + Fibula)	+ 1468.833 ± 296
22.457 Humerus	+ 871.137 ± 327	12.472 Humerus	+ 2529.405 ± 355
32.817 (Radius + Ulna)	+ 800.010 ± 357	16.853 (Radius + Ulna)	+ 2576.237 ± 388
108.992 Clavicle	+ 1833.228 ± 420	56.457 Clavicle	+ 3280.862 ± 385
16.197 Innominate	+ 1315.164 ± 241	12.678 Innominate	+ 2306.559 ± 274
3.739 Skull	+ 1760.950 ± 416	No significant correlation to Skull	
Femur weight =		Femur weight =	
.089 Total skeleton	+ 27.593 ± 28	.076 Total skeleton	+ 70.915 ± 23
1.121 (Tibia + Fibula)	+ 72.505 ± 26	1.023 (Tibia + Fibula)	+ 89.930 ± 21
1.965 Humerus	+ 109.678 ± 41	1.407 Humerus	+ 188.383 ± 28
3.022 (Radius + Ulna)	+ 88.023 ± 39	1.988 (Radius + Ulna)	+ 183.385 ± 32
9.120 Clavicle	+ 204.009 ± 48	No significant correlation to Clavicle	
1.470 Innominate	+ 139.354 ± 34	1.123 Innominate	+ 218.453 ± 27
.240 Skull	+ 246.713 ± 54	No significant correlation to Skull	
Tibia + Fibula weight =		Tibia + Fibula weight =	
.071 Total skeleton	+ 5.292 ± 23	.058 Total skeleton	+ 56.488 ± 23
.733 Femur	+ .572 ± 21	.726 Femur	+ 17.745 ± 18
1.650 Humerus	+ 49.532 ± 32	1.118 Humerus	+ 138.634 ± 25
2.512 (Radius + Ulna)	+ 33.443 ± 30	1.824 (Radius + Ulna)	+ 105.431 ± 25
7.415 Clavicle	+ 133.187 ± 39	No significant correlation to Clavicle	
1.100 Innominate	+ 98.584 ± 31	.785 Innominate	+ 181.783 ± 27
.201 Skull	+ 164.481 ± 43	No significant correlation to Skull	
Humerus weight =		Humerus weight =	
.932 Total skeleton	+ 16.634 ± 12	.029 Total skeleton	+ 29.575 ± 17
.278 Femur	+ 38.482 ± 15	.392 Femur	+ .078 ± 15
.352 (Tibia + Fibula)	+ 46.336 ± 15	.439 (Tibia + Fibula)	+ 23.091 ± 16
1.250 (Radius + Ulna)	+ 19.021 ± 12	1.237 (Radius + Ulna)	+ 17.367 ± 14
3.765 Clavicle	+ 67.482 ± 17	No significant correlation to Clavicle	
.515 Innominate	+ 57.576 ± 14	.508 Innominate	+ 73.608 ± 17
.089 Skull	+ 92.025 ± 20	No significant correlation to Skull	

## APPENDIX B (Continued)

WHITE				NEGRO			
Radius + Ulna weight =				Radius + Ulna weight =			
.022 Total skeleton	+	14.109 ±	8	.015 Total skeleton	+	52.265 ±	11
.197 Femur	+	25.691 ±	10	.203 Femur	+	33.718 ±	10
.250 (Tibia + Fibula)	+	31.077 ±	9	.263 (Tibia + Fibula)	+	34.257 ±	9
.580 Humerus	+	18.262 ±	8	.454 Humerus	+	44.323 ±	9
2.768 Clavicle	+	43.976 ±	11	1.824 Clavicle	+	77.057 ±	11
.341 Innominate	+	43.694 ±	10	No significant correlation to Innominate			
.064 Skull	+	63.254 ±	14	No significant correlation to Skull			
Clavicle weight =				Clavicle weight =			
.005 Total skeleton	+	1.969 ±	3	.004 Total skeleton	+	2.471 ±	3
.040 Femur	+	6.348 ±	3	No significant correlation to Femur			
.049 (Tibia + Fibula)	+	7.881 ±	3	No significant correlation to (Tibia + Fibula)			
.115 Humerus	+	4.966 ±	3	No significant correlation to Humerus			
.184 (Radius + Ulna)	+	2.937 ±	3	.169 (Radius + Ulna)	+	2.911 ±	3
.074 Innominate	+	9.026 ±	3	No significant correlation to Innominate			
.017 Skull	+	10.864 ±	3	No significant correlation to Skull			
Innominate weight =				Innominate weight =			
.052 Total skeleton	—	38.985 ±	14	.049 Total skeleton	—	45.861 ±	17
.468 Femur	—	7.774 ±	19	.514 Femur	—	36.264 ±	18
.535 (Tibia + Fibula)	+	22.849 ±	22	.506 (Tibia + Fibula)	+	16.255 ±	22
1.174 Humerus	+	5.053 ±	22	.834 Humerus	+	42.324 ±	21
1.665 (Radius + Ulna)	+	6.630 ±	22	No significant correlation to (Radius + Ulna)			
5.442 Clavicle	+	60.784 ±	27	No significant correlation to Clavicle			
.160 Skull	+	75.231 ±	29	No significant correlation to Skull			
Skull weight =				Skull weight =			
.140 Total skeleton	+	74.936 ±	81	No significant correlation to total skeleton			
.896 Femur	+	309.714 ±	103	No significant correlation to Femur			
1.146 (Tibia + Fibula)	+	331.875 ±	102	No significant correlation to (Tibia + Fibula)			
2.368 Humerus	+	315.520 ±	104	No significant correlation to Humerus			
3.646 (Radius + Ulna)	+	289.313 ±	102	No significant correlation to (Radius + Ulna)			
14.865 Clavicle	+	341.674 ±	101	No significant correlation to Clavicle			
1.877 Innominate	+	331.657 ±	98	No significant correlation to Innominate			

## REVIEWS

PHYSIQUE AND DELINQUENCY. By Sheldon and Eleanor Glueck. xviii + 339 pp. Harper and Brothers, 1956. \$6.00.

Sheldon and Eleanor Touroff Glueck are the best-known authorities on juvenile delinquency, having many thousands of case-analyses, a shelf of published texts, and a useful predictive formula (widely used by parole boards) to their collective credit. Long scornful of any physique factor in crime, whether Lombroso's "atavisms" or Hooton's "biological inferiority," they have devoted a lifetime to discovering the social disruptions that lead to early criminality. Therefore, when they now write "We can not escape the conclusion that differences in body structure can no longer be ignored in assessing the causal involvements of delinquency, and in shaping measures to cope with it," this summary statement on page 265 of *Physique and Delinquency* is news.

As evidence they offer first, data (taken from "Unravelling Juvenile Delinquency") indicating that Boston-area delinquents are much more mesomorphic than the carefully-selected controls, and second, new data that suggest that environmental factors are not uniformly "criminogenic" when Sheldonian physique groupings are taken into account. With initial samples of 500 delinquents and 500 controls, a new method of multiple comparisons devised by Prof. J. W. Tukey, and a discussion of the statistical methods by Dr. Jane Worcester, the ubiquitous problems of sample-size sampling and statistical techniques would seem to be solved.

As to the physique ratings, there is always the problem of looking at pictures and attempting to guess body composition through the use of visual clues. But since these difficulties are constant, and unless Ashton Tenney knew who was delinquent and who was not (and we are told that this was not so), the finding that 60% of the delinquents were mesomorphs as against 31% of the controls would seem to be both statistically and meaningfully significant. Moreover, Dr. Carl C. Seltzer's ratings, which avoided numbers and employed a simple more-than, equal-to and less-than system of assessment yielded essentially similar results with carefully matched pairings. It is possible that the heightened activity of the delinquents built

muscle and speeded up somatic maturation and fatty development. It is possible that the matches were not matched closely enough. However, there is a simple explanation: having muscles helps a lad to get into the gangs that get into trouble.

The multiple comparisons, detailed in over a hundred tables, attempted to discover what home and environmental factors acted with "special force" on endomorphs, mesomorphs and ectomorphs. Most differences between delinquents and law-abiding controls were not physique-specific. Both groups were equally poor, and lived in comparably-depressed areas, and in equally uninviting flats. As a group the delinquents came from homes that were less well-managed, more dependent upon outside aid, and more often coming apart at the emotional seams. But the delinquent mesomorphs managed to grow up in exceptionally dull and lethargic families with fewer interesting and planned activities. And the delinquent ectomorphs experienced maternal deprivation to an excessive degree.

Here the reviewer is not entirely pleased with the Glueck's use of statistics, despite their impressive panel of experts. In the first place they employ significance values to indicate cause. If a particular difference between delinquents and controls is significant, then a causal relationship is inferred. Now this is not uncommon sociological practice, and in many cases the authors are probably right. But Dr. Mainland would not be amused. And second, if a difference is not significant, they reject a causal relationship, even when *N* shifts about like the numbers on an ailing calculator.

By way of example, employment of the mother is claimed to have "its greatest effect in the resultant delinquency of boys of ectomorphic physique" (p. 175) whereas delinquency of the mother "does not contribute with special force to the delinquency of any one body type" (p. 169). But in the first example there were 230 delinquents and 159 controls, and 221 delinquents and 75 controls in the second. To argue that a difference is or is not significant is one thing, to argue cause from a significant difference and lack of cause from one that is not significant under these circumstances does real violence to the null hypothesis. It appears to the viewer that the laborious item-by-item analysis was less productive than a profile analysis or a single measure of distance might have been.

Despite the tables (more than a hundred of them) and despite six appendices, including a rather ambiguous and unrelated description of the Rorschach analyses, the picture is by no means clear. It would seem that the physique factor, apart from the initial findings on mesomorphy, plays a rather small role in "criminogenesis." The title



of the book and the two concluding chapters are much more dramatic than the findings. One might say that the absence of a father with whom a lad can identify is in itself a predisposing factor, except perhaps for ectomorphs, who apparently need a mother too.

That *Physique and Delinquency* is dedicated to the memory of Earnest A. Hooton should not go unnoticed: though the Gluecks disagreed with him for years, it did not lessen their admiration for his qualities. And this unusual couple may be credited for the first investigation of why individuals differing in physique do, at times, behave differently. Sheldon's explanation involves biological predestination: the Gluecks suggest selective or differential responses to common cultural causes. Since parents do alter their expectancies to meet individual capabilities, many of the answers may lie in discovering how differences in physique are perceived, how they are dealt with, and what happens when insight is lacking.

STANLEY M. GARN  
*Fels Research Institute*

---

A SYLLABUS IN ROENTGENOGRAPHIC CEPHALOMETRY. By Wilton M. Krogman and Viken Sassouni. Pp. v + 366, Philadelphia Center for Research in Child Growth, Philadelphia, 1957. \$12.50.

This loose leaf syllabus ranges far beyond the title. An orthodontist and anthropologist have combined to produce the first real text on radiographic cephalometry. After touching briefly on the historical development of radiographic cephalometry, the authors unfortunately give only an elementary explanation of the meaning and derivation of normative standards. To conclude the chapter a discussion of statistical methods so short as to be useless is added to an account of the numerous methods used in examining craniofacial relationships.

The next two chapters constitute the crux of the syllabus. In chapter II there is a brief description of radiographic techniques, the types of cephalostats (both human and animal), and mode of tracing the films obtained. The radiographic atlas (chapter III) is well presented and, if the points and planes are endorsed by the Orthodontic Workshop, would make the publication of real practical value.

One wonders why the section on collateral research (chapter 4) which ranges from the evolution of facial form to a discussion of the classification of malocclusion, has been included. Perhaps the section serves to point out avenues for future research in radiographic cephalometry. The unique advantages of radiographic cephalometry in the study of craniofacial growth, both cross sectionally and serially, are well presented. Lastly, a review has been made of some 44 radiographic analyses. The reviewer fears these may confuse the beginner in radiographic cephalometry, since analyses for specific research projects have been lumped together with the broader analyses of facial form.

In general, the syllabus is valuable to those familiar with orthodontic jargon and who have some experience with radiographic cephalometry.

A. H. CRAVEN

R. E. MOYERS

University of Michigan,  
School of Dentistry.

---

STRESS AND STRAIN IN BONES. THEIR RELATION TO FRACTURES AND OSTEOGENESIS. By F. Gaynor Evans. Pp X + 245, (American Lecture Series No. 296). Charles C Thomas, Springfield, Ill. 1957.

The publication of Evan's monograph *Stress and Strain in Bones* appears to this reviewer to be of considerable significance in the field of bone biology. Twenty years have elapsed since Murray's ('36) classic survey of knowledge concerning intrinsic and extrinsic biomechanical factors in the development, maintenance, and alteration of skeletal form. These two decades have been a period of very rapid advance in all areas of skeletal tissue biology, specially those in which use can be made of the newer techniques in chemistry, physics, and engineering. Syntheses of the multitude of individual investigations have recently appeared: *Bone. An Introduction to the Physiology of Skeletal Tissue* (Melean and Urist, '55), *Bone Structure and Metabolism* (Ciba Foundation Symposium, '56), *The Biochemistry and Physiology of Bone* (Edited by Bourne, '56). To these one may add, for completeness, the somewhat earlier *Organization of Bones* (Lacroix, French ed., '49 and English, '51) and the new edition of *Bone and Bones* (Weinmann and Sicher, '56) which in its 1947 edition was the only general treatise on skeletal tissue available. Only two of these

works deal to any appreciable degree with the area emphasized by Murray. Weinmann and Sicher briefly discuss normal functional adaptation and treat extensively the subject of adaptational deformity. Bourne's volume presents "bone as a mechanical engineering problem," skeletal development *in vitro*, and the growth of bone all in survey fashion in chapters by Bell, H. B. Fell, and Sissions, respectively.

Evans' is the first definitive work to deal specifically and exclusively with (as its title indicates) stress and strain in bones in relation to fractures and osteogenesis. The text is divisible into five parts: definition of principles and terms and a brief survey of techniques applicable to the problem (6% of text); a criticism of early attempts to study stress and strain by use of two dimensional models or by mathematical analysis of form (8%); a thorough presentation of the results of modern bioengineering studies of stress and strain magnitude and direction in the axial and appendicular skeleton (36%); a discussion of the role of stress and strain in bone architecture, fracture healing, and embryonic development, and the biological factors influencing breaking strength (28%); finally, the fatigue strength of bone in tension, compression, torsion, bending, and shearing (22%).

The author writes in a clear, concise manner and all engineering terms are defined and illustrated as encountered. There is, in addition, a glossary of such terms at the end of the text. The bibliography lists only those works cited, but the historical review in the text is such that the major literature in the field is considered. Each chapter beyond the two introductory ones ends in a most valuable and complete summary. The reviewer was disappointed to find that there was no summary for the book as a whole; admittedly a general summary might have been difficult to present, but as it stands, the work ends rather abruptly.

*Stress and Strain in Bones* is not a conjectural or philosophical work. Rather, Evans has given us a categorical presentation of the current information in a field in which he has been a major contributor. It is a book from which many bone-biologists will have to make applications to their own areas of interest. This is hardly a fault and is perhaps even a virtue of Evans' approach. Certainly *Stress and Strain in Bone* fills one of the major gaps in our basic library. One hopes that some of the other expanding areas will be similarly treated in the near future.

WILLIAM J. L. FELTS  
*University of Minnesota*

ESSAYS IN LINGUISTICS. By Joseph H. Greenberg. Viking Fund Publications in Anthropology No. 24 (New York, 1957) vii + 108.

An excellent collection of essays with fresh treatments of old problems as well as interesting presentations of new ones. The volume might well serve as a refresher in linguistics for those in the other social sciences whose exposure to linguistics antedates the present decade. Biologists will be especially interested in Greenberg's view of "Language as a Sign System" and in the chapter "Language and Evolutionary Theory." The author has made excellent use of some of the newer topics in mathematical logic that are just coming into their own in the social sciences in general and in linguistics in particular. In short, this is an elegant and sophisticated survey of linguistic theory.

HERBERT H. PAPER  
*University of Michigan*



# INDEX

- A** STUDY of the formation of the sural nerve in adult man ..... 137
- ABO blood groups in a sample of hospital patients receiving blood transfusions, the distribution of ..... 341
- Abstracts and list of members, Proceedings, The American Association of Physical Anthropologists ..... 421
- Adult man, a study of the formation of the sural nerve in ..... 137
- Age determination, distortion of the pubic symphyseal surface in females and its effect on ..... 9
- American Indians, the Kell antigen in. With a note about anti-Kell sera ..... 149
- American-born and native Japanese children, a comparison of the physical growth and development of ..... 489
- Anthropologists, the American Association of Physical. Proceedings, abstracts and list of members ..... 421
- Anthropometric caliper, a counter-type. The Harpenden anthropometer ..... 277
- Anti-Kell sera, with a note about. The Kell antigen in American Indians ..... 149
- Australian aborigines at Haast's Bluff, Central Australia, a blood group genetical survey in ..... 547
- Australian aboriginal mandible, the chin region of the ..... 517
- BAER, MELVYN J. AND JOSEPHINE DURKATZ.** Bilateral asymmetry in skeletal maturation of the hand and wrist: A roentgenographic analysis ..... 181
- BAKER, PAUL T. AND RUSSELL W. NEWMAN.** The use of bone weight for human identification ..... 601
- BEHAR, ISAAC.** See Stewart, Peter A.
- Bilateral asymmetry in skeletal maturation of the hand and wrist: A roentgenographic analysis ..... 181
- BIRD, G. W. G., T. K. JAYARAM, ELIZABETH W. IKIN, A. E. MOURANT AND H. LEHMANN.** The blood groups and haemoglobin of the Gorkhas of Nepal ..... 163
- BLACKWOOD, H. J. J.** The double-headed mandibular condyle ..... 1
- Blood group genetical survey in Australian aborigines at Haast's Bluff, Central Australia, a ..... 547
- Blood group genetical survey in Eastern and Central Polynesians, a ..... 357
- Blood groups and haemoglobin of the Gorkhas of Nepal, the ..... 163
- Blood groups of South American Indians, the ..... 555
- Bone weight for human identification, the use of ..... 601
- Book Notes ..... 415
- BOUCHER, BARBARA J.** Sex differences in the foetal pelvis ..... 581
- BRAIN, P.** See Singer, R. ..... 91
- BROMAN, GEORGE E., JR.** Precondylar tubercles in American Whites and Negroes ..... 125
- BUDTZ-OLSEN, O. E.** See Singer, R. ..... 91
- BUETTNER-JANUSCH, JOHN.** The distribution of ABO blood groups in a sample of hospital patients receiving blood transfusions ..... 341
- CASLEY-SMITH, J. R.** See Simmons, R. T. ..... 547
- Change in the profile of the osseous chin during childhood ..... 247
- Chin region of the Australian aboriginal mandible, the ..... 517
- CHOWN, BRUCE AND MARION LEWIS.** The Kell antigen in American Indians. With a note about anti-Kell sera ..... 149
- CLELAND, J. B.** See Simmons, R. T. ..... 547
- Comments and Communications: Concurrent fat loss and gain: Addendum* ..... 157
- Comparative study of the primate femur by means of the stresscoat and the split-line techniques, a ..... 59
- Comparison of split-line patterns in the skulls of a juvenile and an adult male gorilla, a ..... 49
- Comparison of the physical growth and development of American-born and native Japanese children, a ..... 489
- Cranial vault, the: Factors of size and shape ..... 19
- D**ISTORTION of the pubic symphyseal surface in females and its effect on age determination ..... 9
- Distribution of ABO blood groups in a sample of hospital patients receiving blood transfusions ..... 341
- Double-headed mandibular condyle, the ..... 1
- DURKATZ, JOSEPHINE.** See Baer, Melvyn J. ..... 181
- E**ARLIEST use of indices for sexing pelvises, the ..... 537
- Eruption of primary teeth in Korean rural children ..... 261
- Estimation of skeletal age from combined maturational activity ..... 399
- EVANS, F. GAYNOR AND CHARLES W. GOFF.** A comparative study of the primate femur by means of the stresscoat and the split-line techniques ..... 59
- F**acial and pubic hair growth in white women, variation in ..... 171
- FERRIMAN, D. G.** See Thomas, P. Kynaston ..... 171
- Foetal pelvis, sex differences in the ..... 581
- Fossil and modern man, tooth eruption sequence in ..... 469
- Frontal and parietal bones in white males, postnatal growth of the ..... 367
- G**ARN, STANLEY MARION. See Koski, Pentti Kalevi ..... 469



- GARN, STANLEY MARION, KALEVI KOSKI AND ARTHUR B. LEWIS. Problems in determining the tooth eruption sequence in fossil and modern man . . . . . 313
- Galvanic skin response in monkeys with prehensile tails . . . . . 333
- Genetical survey in Australian aborigines at Haast's Bluff, Central Australia, a blood group . . . . . 547
- GOFF, CHARLES W. See Evans, F. Gaynor . . . . . 59
- GOLDSTEIN, MARCUS S. Skeletal pathology of early Indians in Texas . . . . . 299
- Gorilla, a comparison of split-line patterns in the skulls of a juvenile and an adult male . . . . . 49
- Gorkhas of Nepal, the blood groups and haemoglobin of the . . . . . 163
- GRAYDON, J. J. See Simmons, R. T. . . . . 357
- GREULICH, WILLIAM WALTER. A comparison of the physical growth and development of American-born and native Japanese children . . . . . 489
- H**AEMOGLOBIN of the Gorkhas of Nepal, the blood groups and . . . . . 163
- Hair growth in white women, variation in facial and pubic . . . . . 171
- Hand and wrist, bilateral asymmetry in skeletal maturation of the: A roentgenographic analysis . . . . . 181
- Harpender anthropometer, the. A counter-type anthropometric caliper . . . . . 277
- HILLABY, JOHN. The Kwangsi jaw . . . . . 281
- HOWELLS, W. W. The cranial vault: Factors of size and shape . . . . . 19
- HOYME, LUCILE E. The earliest use of indices for sexing pelvis . . . . . 537
- HUELKE, DONALD F. A study of the formation of the sural nerve in adult man . . . . . 137
- HULSE, FREDERICK S. Linguistic barriers to gene-flow. The blood-groups of the Yakima, Okanagon and Swinomish Indians . . . . . 235
- Human identification, the use of bone weight for . . . . . 601
- I**KIN, ELIZABETH W. See Bird, G. W. G. . . . . 163
- Indians in Texas, skeletal pathology of early . . . . . 299
- Indians, the blood group of South American . . . . . 555
- Ischial callosities as sleeping adaptations . . . . . 269
- J**APANESE children, a comparison of the physical growth and development of American-born and native . . . . . 489
- JAYARAM, T. K. See Bird, G. W. G. . . . . 163
- K**ELL antigen in American Indians, the. With a note about anti-Kell sera . . . . . 149
- Korean rural children, eruption of primary teeth in . . . . . 261
- KOSKI, KALEVI. See Garn, Stanley Marion . . . . . 313
- KOSKI, KALEVI AND STANLEY MARION GARN. Tooth eruption sequence in fossil and mesoderm man . . . . . 469
- Kwangsi jaw, the . . . . . 281

- L**EHMANN, H. See Bird, G. W. G. . . . . 163
- LEWIS, ARTHUR B. See Garn, Stanley Marion . . . . . 313
- LEWIS, MARION. See Chown, Bruce . . . . . 149
- Linguistic barriers to gene-flow. The blood-groups of the Yakima, Okanagon and Swinomish Indians . . . . . 235
- M**ALAGASY of Madagascar, physical features, sickling and serology of the . . . . . 91
- MCKERN, THOMAS W. Estimation of skeletal age from combined maturational activity . . . . . 399
- Members, Proceedings, abstracts and list of. The American Association of Physical Anthropologists . . . . . 421
- MEREDITH, HOWARD V. Change in the profile of the osseous chin during childhood . . . . . 247
- Modern man, tooth eruption sequence in fossil and . . . . . 469
- Monkeys with prehensile tails, galvanic skin response in . . . . . 333
- MOURANT, A. E. See Bird, G. W. G. . . . . 163
- MURPHY, THOMAS. The chin region of the Australian aboriginal mandible . . . . . 517
- Muscle growth and function in relation to skeletal morphology . . . . . 197
- N**EWMAN, RUSSELL W. See Baker, Paul T. . . . . 601
- O**AKLEY, KENNETH P. Stratigraphical age of the Swanscombe skull Okanagon and Swinomish Indians, the blood-groups of the Yakima . . . . . 235
- Osseous chin during childhood, change in the profile of the . . . . . 247
- OTTEN, CHARLOTTE M. See Thieme, Frederick P. . . . . 387
- P**ARIETAL bones in white males, postnatal growth of the frontal and . . . . . 367
- Physical features, sickling and serology of the Malagasy of Madagascar . . . . . 91
- Physical growth and development of American-born and native Japanese children, a comparison of the . . . . . 489
- Postnatal growth of the frontal and parietal bones in white males . . . . . 367
- Precondylar tubercles in American Whites and Negroes . . . . . 125
- Primary teeth in Korean rural children, eruption of . . . . . 261
- Primate femur by means of the stresscoat and the split-line techniques, a comparative study of the . . . . . 59
- Problems in determining the tooth eruption sequence in fossil and modern man . . . . . 313
- Proceedings, abstracts and list of members. The American Association of Physical Anthropologists . . . . . 421
- R**EVIEWS:
- A syllabus in roentgenographic cephalometry. Wilton M. Krogman and Viken Sassouni. *Reviewed by* A. H. Craven and R. E. Moyers . . . . . 621
- Analyse de la variation des caracteres physiques humains en une region de l'Afrique centrale: Ruanda-Urundi et Kivu. J. Hiernaux. *Reviewed by* W. W. Howells . . . . . 409

- Bones for the archaeologist. I. W. Cornwall. *Reviewed by* Arthur J. Jelinek . . . . . 296
- Essays in linguistics. Joseph H. Greenberg. *Reviewed by* Herbert H. Paper . . . . . 624
- Physique and delinquency. Sheldon Glueck and Eleanor Glueck. *Reviewed by* Stanley M. Garn . . . . . 619
- Prehistoric man in Denmark. (A study in physical anthropology.) Kurt Broste, J. Balslev Jorgensen, C. J. Becker and Johannes Brondsted. *Reviewed by* W. S. Laughlin . . . . . 413
- Primatologia: Handbook of primatology. H. Hofer, A. H. Schultz and D. Stark. *Reviewed by* James A. Gavan . . . . . 293
- Stress and strain in bones. Their relation to fractures and osteogenesis. F. Gaynor Evans. *Reviewed by* William J. L. Felts . . . . . 622
- The aetiology of irregularity and malocclusion of the teeth. James Couper Brash, H. T. A. McKeag and James H. Scott. With an appendix by Miriam L. Tildesley. *Reviewed by* Stanley M. Garn . . . . . 297
- RIOPELLE, ARTHUR J. See Stewart, Peter A. . . . . 333
- Roentgenographic analysis, a. Bilateral asymmetry in skeletal maturation of the hand and wrist . . . . . 181
- S**ALZANO, FRANCISCO M. The blood groups of South American Indians . . . . . 555
- SAUGRAIN, J. See Singer, R. . . . . 91
- SCOTT, J. H. Muscle growth and function in relation to skeletal morphology . . . . . 197
- SEMPLE, N. M. See Simmons, R. T. . . . . 547
- Sex differences in the foetal pelvis . . . . . 581
- SIMMONS, R. T., AND J. J. GRAYDON. A blood group genetical survey in Eastern and Central Polynesians . . . . . 357
- SIMMONS, R. T., N. M. SEMPLE, J. B. CLELAND AND J. R. CASLEY-SMITH. A blood group genetical survey in Australian aborigines at Haast's Bluff, Central Australia . . . . . 547
- SINGER, R., O. E. BUDTZ-OLSEN, P. BRAIN AND J. SAUGRAIN. Physical features, sickling and serology of the Malagasy of Madagascar . . . . . 91
- Skeletal morphology, muscle growth and function in relation to . . . . . 197
- Skeletal pathology of early Indians in Texas . . . . . 299
- SMITH, RICHARD P. See Stewart, Peter A. . . . . 333
- STEWART, PETER, A., RICHARD P. SMITH, ISAAC BEHAR AND ARTHUR J. RIOPELLE. Galvanic skin response in monkeys with prehensile tails . . . . . 333
- STEWART, T. D. Distortion of the pubic symphyseal surface in females and its effect on age determination . . . . . 9
- Stratigraphical age of the Swanscombe skull . . . . . 253
- Stresscoat and the split-line techniques, a comparative study of the primate femur by means of the . . . . . 59
- Sural nerve in adult man, a study of the formation of the . . . . . 137
- Swanscombe skull, stratigraphical age of the . . . . . 253
- Swinomish Indians, the blood-groups of the Yakima, Okanagon and . . . . . 235
- T**ANNER, J. M., AND R. H. WHITEHOUSE. The Harpenden anthropometer. A countertype anthropometric calibrator . . . . . 277
- TAPPEN, N. C. A comparison of split-line patterns in the skulls of a juvenile and an adult male gorilla . . . . . 49
- The American Association of Physical Anthropologists. Proceedings, abstracts and list of members . . . . . 421
- THIEME, FREDERICK P. AND CHARLOTTE M. OTTEN. The unreliability of blood typing aged bone . . . . . 387
- THOMAS, P. KYNASTON AND D. G. FERRIMAN. Variation in facial and pubic hair growth in white women . . . . . 171
- Tooth eruption sequence in fossil and modern man . . . . . 469
- Tooth eruption sequence in fossil and modern man, problems in determining the . . . . . 313
- TROTTER, MILDRED. Viking Fund Medalist for 1956 . . . . . 287
- V**ARIATION in facial and pubic hair growth in white women . . . . . 171
- Viking Fund Medalist for 1956 (Mildred Trotter) . . . . . 287
- W**ASHBURN, S. L. Ischial callosities as sleeping adaptations . . . . . 269
- WHITEHOUSE, R. H. See Tanner, J. M. . . . . 277
- Y**AKIMA, Okanagon and Swinomish Indians, the blood-groups of . . . . . 235
- YOUNG, RICHARD W. Postnatal growth of the frontal and parietal bones in white males . . . . . 367
- YUN, DUK JIN. Eruption of primary teeth in Korean rural children . . . . . 261

